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AGRICULTURAL RESEARCH INSTITUTE
PUSA

REPORT

OF THE

FORTY-SIXTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

GLASGOW IN SEPTEMBER 1876

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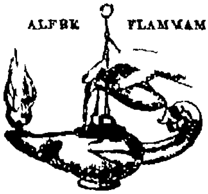

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OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

THE ASSOCIATION contemplates no interference with the ground occupied by other institutions Its objects are —To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

LIFE MEMBERS shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

ANNUAL SUBSCRIBERS shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis* but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.

2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.

3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]

4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]

5. Associates for the year, subject to the payment of One Pound.

6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices*, viz. two thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than* 100 *copies remain*, at one third of the Publication Price. Application to be made at the Office of the Association, 22 Albemarle Street, London, W.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the Arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant General Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.

1. The President for the time being of any Scientific Society publishing Transactions or, in his absence, a delegate representing him. *Claims under this Rule to be sent to the Assistant General Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organizing Sectional Committees.*

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organizing Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections†, and of preparing Reports thereon, and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first Meeting.

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* Passed by the General Committee, Edinburgh, 1871.

† *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be

An Organizing Committee may also hold such preliminary Meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to settle the terms of their Report, after which their functions as an Organizing Committee shall cease.

*Constitution of the Sectional Committees**.

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day, in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday at 2 P.M., on the following Thursday, Friday, Saturday, Monday, and Tuesday, from 10 to 11 A.M., punctually, for the objects stated in the Rules of the Association, and specified below.

The business is to be conducted in the following manner:—

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Transactions. He will next proceed to read the Report of the Organizing Committee[†]. The List of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the

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read, are now as far as possible determined by Organizing Committees for the several Sections *before the beginning of the Meeting*. It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each Author should prepare an Abstract of his Memoir, of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before........................., addressed thus—"General Secretaries, British Association, 22 Albemarle Street, London, W. For Section ......" If it should be inconvenient to the Author that his Paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note.

* Passed by the General Committee, Edinburgh, 1871.

[†] This and the following sentence were added by the General Committee, 1871.

Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printers, who are charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section should call at the Printing Office and revise the proof each evening

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant General Secretary

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xix), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted, to name individuals or Committees for the execution of such Reports or researches, and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and one of them appointed to act as Secretary, for insuring attention to business.*

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant General Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee

Notices Regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in Science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Individual or the Member first named of a Committee to whom a money grant has been made must (previously to the next meeting of the Association) forward to the General

Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one meeting of the Association expire *a week before* the opening of the ensuing Meeting, nor is the Treasurer authorized, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Member first named is the only person entitled to call on the Treasurer, Professor A. W. Williamson, University College, London, W.C., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation from 10 to 11 daily. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At 11 precisely the Chair will be taken, and the reading of communications, in the order previously made public, be commenced. At 3 P.M. the Sections will close.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1.—To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.

2.—To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Assistant General Secretary.

3.—Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed, during the whole time for which they are engaged except when employed on messages by one of the Officers directing these Rooms

Committee of Recommendations

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science

All Recommendations of Grants of Money Requests for Special Researches and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations

Local Committees

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire

Officers.

A President two or more Vice Presidents one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee

Council

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee The Council may also assemble for the despatch of business during the week of the Meeting

Papers and Communications

The Author of any paper or communication shall be at liberty to reserve his right of property therein

Accounts

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement

PRESIDENTS	VICE PRESIDENTS	LOCAL SECRETARIES
The EARL FITZWILLIAM D C L F R S F G S &c. YORK September 27 1831	Rev W Vernon Harcourt M A F R S F G S	William Gray jun F G S Professor Phillips M A F R S F G S.
The REV W BUCKLAND D D F R S. F G S &c OXFORD June 19 1832	Sir David Brewster F R S L & E &c Rev W Whewell, F R S Pres Geol Soc.	Professor Daubeny M D F R S &c. Rev Professor Powell M A F R S &c
The REV ADAM SEDGWICK M A V P R S V P G S CAMBRIDGE June 25 1833	G B Airy F R S Astronomer Royal &c John Dalton D C L F R S	Rev Professor Henslow M A F L S F G S Rev W Whewell F R S
SIR T MACDOUGALL BRISBANE K C B D C L F R S L & E EDINBURGH September 8 1834	Sir David Brewster F R S &c Rev T R Robinson, D D	Professor Forbes F R S L & E &c Sir John Robinson Sec R S E
The REV PROVOST LLOYD LL D DUBLIN August 10 1835	Viscount Oxmantown F R S F R A S Rev W Whewell F R S &c	Sir W R Hamilton Astron Royal of Ireland &c. Rev Professor Lloyd F R S
The MARQUIS OF LANSDOWNE D C L F R S &c BRISTOL, August 22 1836	The Marquis of Northampton F R S Rev W D Conybeare F R S F G S J C Prichard M D F R S	Professor Daubeny M D F R S &c V F Hovenden Esq
The EARL OF BURLINGTON F R S F G S Chancellor of the University of London LIVERPOOL September 11 1837	The Bishop of Norwich P L S F G S John Dalton D C L F R S Sir Philip de Grey Egerton Bart F R S F G S Rev W Whewell, F R S	Professor Traill M D Wm Wallace Currie Esq Joseph N Walker Pres Royal Institution Liverpool
The DUKE OF NORTHUMBERLAND F R S F G S &c. NEWCASTLE-ON TYNE August 20 1838	The Bishop of Durham F R S F S A The Rev W Vernon Harcourt F R S &c Prideaux John Selby Esq F R S E	John Adamson F L S &c Wm Hutton F G S Professor Johnston M A F R S
The REV W VERNON HARCOURT M.A. F R S &c BIRMINGHAM August 26, 1839	Marquis of Northampton Earl of Dartmouth The Rev T R Robinson D D John Corrie Esq F R S Very Rev Principal Macfarlane	George Barker Esq F R S Peyton Blakiston M D Joseph Hodgson Esq F R S Follett Osler Esq.
The MARQUIS OF BREADALBANE F R S GLASGOW September 1 1840	Major General Lord Greenock F R S E Sir David Brewster F R S Sir T M Brisbane Bart F R S The Earl of Mount Edgecumbe	Andrew Liddell Esq Rev J P Nicol, LL.D John Strang Esq
The REV PROFESSOR WHEWELL F R S &c. PLYMOUTH July 29 1841	The Earl of Morley Lord Eliot, M P Sir C Lemon Bart. Sir D T Acland Bart	W Snow Harris, Esq F R S Col Hamilton Smith F L S Robert Were Fox Esq Richard Taylor jun Esq.
The LORD FRANCIS EGERTON F G S MANCHESTER June 23, 1842	John Dalton D C L F R S Hon and Rev W Herbert, F L S &c Rev A Sedgwick M A F R S W C Henry M D F R S Sir Benjamin Heywood, Bart	Peter Clare Esq F R A S W Fleming M D James Heywood Esq F R S
The EARL OF ROSSE F R S. CORK, August 17 1843.	Earl of Listowel Viscount Adare Sir W R Hamilton Pres R I A. Rev T R Robinson D D	Professor John Stevelly M A Rev Jos Carson F T C Dublin William Keleher Esq Wm Clear Esq
The REV G PEACOCK D.D (Dean of Ely) F R S YORK, September 26 1844	Earl Fitzwilliam F R S Viscount Morpeth F G S The Hon John Stuart Wortley M P Sir David Brewster K H F R S Michael Faraday Esq D C L F R S Rev W V Harcourt, F R S	William Hatfeild Esq F G S Thomas Meynell Esq F L S Rev W Scoresby LL D F R S William West, Esq

1876.

SIR JOHN F W HERSCHEL, Bart. F.R.S., &c CAMBRIDGE, June 19 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev J Graham D D Rev G Ainslie, D D G B Airy Esq M.A. D C.L F R S The Rev Professor Sedgwick, M A F R.S	William Hopkins Esq M A F R S. Professor Ansted, M A F R S
SIR RODERICK IMPEY MURCHISON G C.St.S F R.S SOUTHAMPTON September 10 1846.	The Marquis of Winchester The Earl of Yarborough D C L Lord Ashburton D C.L Viscount Palmerston, M P Right Hon Charles Shaw Lefevre M P Sir George T Staunton Bart. M P D C L. F R S The Lord Bishop of Oxford F R S Professor Owen M D F R.S Professor Powell, F R S	Henry Clark, M D T H C Moody Esq
SIR ROBERT HARRY INGLIS, Bart. D C L F R.S., M.P for the University of Oxford OXFORD June 23, 1847	The Earl of Rosse F R S The Lord Bishop of Oxford, F R S The Vice-Chancellor of the University Thomas G Bucknall Estcourt, Esq D C L M P for the University of Oxford Very Rev the Dean of Westminster D D F R S Professor Daubeny M D F R.S The Rev Prof Powell M A F R S	Rev Robert Walker M A F R S H Wentworth Acland Esq B.M
The MARQUIS OF NORTHAMPTON President of the Royal Society &c. SWANSEA, August 9 1848	The Marquis of Bute, K T Viscount Adare F R.S Sir H T De la Beche F R S. Pres G S The Very Rev the Dean of Llandaff F R.S Lewis W Dillwyn Esq F R S W R Grove Esq F R S J H Vivian Esq M P F R S The Lord Bishop of St David s.	Matthew Moggridge Esq D Nicol M D
The REV T R. ROBINSON D D M R I.A F R A S BIRMINGHAM September 12, 1849	The Earl of Harrowby The Lord Wrottesley F R S Right Hon Sir Robert Peel, Bart M P D C L F R S Charles Darwin Esq M A F R S Sec G S Professor Faraday D C L F R S Sir David Brewster K.H LL D F R S Rev Prof Willis M A F R.S	Captain Tindal R.N William Wills Esq Bell Fletcher Esq M D James Chance Esq
SIR DAVID BREWSTER, K H. LL.D F R S L & E. Principal of the United College of St. Salvator and St. Leonard, St. Andrews. EDINBURGH July 21 1850	Right Hon the Lord Provost of Edinburgh The Earl of Cathcart, K C B F R S E The Earl of Rosebery K T D C L F R.S Right Hon David Boyle Lord Justice-General F R S E General Sir Thomas M Brisbane Bart. D C L F R.S Pres R S E Very Rev John Lee D D V P R S E Principal of the University of Edinburgh Professor W P Alison M D V P R S E Professor J D Forbes F R S Sec R S E	Rev Professor Kelland M A F R S L & E Professor Balfour M D F R S E F L S James Tod, Esq F R S E
GEORGE BIDDELL AIRY Esq D C L. F R.S Astronomer Royal IPSWICH, July 2, 1851	The Lord Rendlesham M P The Lord Bishop of Norwich Rev Professor Sedgwick M A F.R S Rev Professor Henslow M A F L S Sir John P Boileau, Bart F R S Sir William F F Middleton Bart. J C Cobbold, Esq M P T B Western Esq	Charles May Esq F R A S Dillwyn Sims Esq George Arthur Biddell Esq George Ransome Esq., F L.S
COLONEL EDWARD SABINE Royal Artillery Treas & V.P of the Royal Society BELFAST September 1 1852	The Earl of Enniskillen, D C L. F R.S The Earl of Rosse, M R.I A Pres. R.S Sir Henry T De la Beche F R.S Rev Edward Hincks D D M R I A Rev P S Henry D D Pres Queen s College Belfast Rev T R Robinson D D Pres. R I.A., F R.A.S Professor G G Stokes, F R.S Professor Stevelly LL.D	W J C Allen Esq William M Gee, M D Professor W P Wilson

PRESIDENTS	VICE PRESIDENTS	LOCAL SECRETARIES
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The EARL OF HARROWBY F R.S Liverpool, September 20 1854	The Lord Wrottesley M.A F R S. F R.A S Sir Philip de Malpas Grey Egerton Bart M P F R S F G S Professor Owen M D LL.D F R.S F L S F G S Rev Professor Whewell, D D F R S Hon. M R.I A., F G.S. Master of Trinity College, Cambridge William Lassell, Esq F R S L & E F R.A S Joseph Brooks Yates F S A F R.G S	Joseph Dickinson M D F R.S Thomas Inman, M D
The DUKE OF ARGYLL, F R.S F G S Glasgow September 12 1855	The Very Rev Principal Macfarlane D D Sir William Jardine Bart. F R S E Sir Charles Lyell M A LL D F R.S James Smith Esq F R S L & E Walter Crum Esq F R S Thomas Graham, Esq M A F R S Master of the Royal Mint Professor William Thomson M A. F R.S	John Strang LL D Professor Thomas Anderson, M D William Gourlie, Esq
CHARLES G B DAUBENY M D LL.D F R.S Professor of Botany in the University of Oxford Cheltenham, August 6, 1856	The Earl of Ducie F R.S F G S The Lord Bishop of Gloucester and Bristol Sir Roderick I Murchison G C St S D C L. F R S Thomas Barwick Lloyd Baker Esq The Rev Francis Close, M A	Capt Robinson R.A. Richard Beamish Esq F R S. John West Hugall, Esq
The REV HUMPHREY LLOYD D D D C L. F R S L. & E., V P.R.I A Dublin August 26, 1857	The Right Honourable the Lord Mayor of Dublin The Provost of Trinity College Dublin The Marquis of Kildare Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron Dublin Sir William R. Hamilton, LL D F R A S Astronomer Royal of Ireland Lieut Colonel Larcom R E LL D F R S Richard Griffith Esq LL D M R I A F R S E F G S	Lundy E Foote Esq Rev Professor Jellett F T C D W Neilson Hancock, LL.D
RICHARD OWEN M D D C L. V P R S F L.S., F G S Superintendent of the Natural-History Departments of the British Museum Leeds, September 22, 185	The Lord Monteagle F R S The Lord Viscount Goderich, M P F R G S. The Right Hon M T Baines, M.A M P Sir Philip de Malpas Grey Egerton Bart M P F R S F G S The Rev W Whewell D D F R.S Hon M R.I A. F G S F R A S. Master of Trinity College, Cambridge James Garth Marshall, Esq M A F G S R. Monckton Milnes Esq D C L M P F R G S	Rev Thomas Hincks, B A W Sykes Ward, Esq F C S Thomas Wilson, Esq M.A
HIS ROYAL HIGHNESS THE PRINCE CONSORT Aberdeen, September 14, 1859	The Duke of Richmond, K G F.R.S The Earl of Aberdeen LL D K G K T., F R.S The Lord Provost of the City of Aberdeen Sir John F W Herschel, Bart. M A D C L., F R S Sir David Brewster K H., D C L F R.S Sir Roderick I Murchison G C St.S D C L. F R.S The Rev W V Harcourt, M.A F R.S The Rev T R Robinson D D F R.S A Thomson, Esq., LL D F R.S., Convener of the County of Aberdeen.	Professor J Nicol F R S.E F G.S. Professor Fuller M.A. John F White, Esq

The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. ... OXFORD, June 27, 1860.	The Earl of Derby, K.G., P C., D C L., Chancellor of the Univ of Oxford. The Rev. F Jeune, D C L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D C.L., F G S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K P, M.A., F R.S., F R.A.S The Lord Bishop of Oxford, D D, F R.S. The Very Rev. H G Liddell, D D, Dean of Christ Church, Oxford Professor Daubeny, M D, LL.D, F R S, F.L.S, F G S Professor Acland, M D., F R.S Professor Donkin, M A, F R.S, F.R.A S	George Rolleston, M D, F L.S. H J S Smith, Esq, M.A., F C.S George Griffith, Esq, M A., F C S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E, F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F R.G.S The Lord Stanley, M P, D C L., F.R.G S. The Lord Bishop of Manchester, D D, F R.S., F G S Sir Philip de M Grey Egerton, Bart., M P, F R.S, F G S. Sir Benjamin Heywood, Bart., F R.S. Thomas Bazley, Esq, M P James Aspinall Turner, Esq, M P James Prescott Joule, Esq, LL.D., F R.S, Pres Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F R.S, M R.I.A, M I.C E. Joseph Whitworth, Esq, F R.S, M I C E.	R. D Darbishire, Esq, B A., F G.S. Alfred Neild, Esq Arthur Ransome, Esq, M.A Professor H E Roscoe, B.A.
The REV. R. WILLIS, M A., F.R.S, Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev the Vice-Chancellor of the University of Cambridge The Very Rev Harvey Goodwin, D D, Dean of Ely The Rev W. Whewell, D D., F R S, Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D C L., F R.S Rev J Challis, M A, F R.S G B Airy, Esq., M A, D C L, F R.S., Astronomer Royal Professor G G Stokes, M.A, D C L., Sec R.S Professor J C. Adams, M.A., D C L., F R.S., Pres C P S.	Professor C. C Babington, M A, F R S., F L S. Professor G D Liveing, M.A. The Rev N M Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D, F.R.S. .... NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C Trevelyan, Bart., M.A Sir Charles Lyell, LL.D, D C L., F R.S, F G.S Hugh Taylor, Esq, Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev Temple Chevallier, B D, F R.A S William Fairbairn, Esq, LL.D, F R.S	A Noble, Esq. Augustus H Hunt, Esq. R. C Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon Lord Portman The Very Reverend the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq, M.P, F R.S, F G S., F S A. A. E Way, Esq., M P Francis H Dickinson, Esq. W. Sanders, Esq, F R.S., F.G S.	C Moore, Esq, F G.S. C. E Davis, Esq. The Rev. H. H Winwood, M A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
JOHN PHILLIPS, Esq., M.A., LL.D., F R.S., F G S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire. The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon Lord Wrottesley, M.A , D C L., F R.S , F R.A.S The Right Reverend the Lord Bishop of Worcester The Right Hon C B Adderley, M P William Scholefield, Esq , M.P. J T Chance, Esq F Osler, Esq , F R S The Rev Charles Evans, M A.	William Mathews, Esq., jun., F.G.S. John Henry Chamberlain, Esq. The Rev G D. Boyle, M A.
WILLIAM R. GROVE, Esq., Q.C., M.A , F R.S. NOTTINGHAM, August 22, 1866	His Grace the Duke of Devonshire, Lord Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J E Denison, M P J C Webb, Esq , High-Sheriff of Nottinghamshire Thomas Graham, Esq , F R S , Master of the Mint Joseph Hooker M D , F R.S , F L S John Russell Hinds, Esq , F R.S , F R.A S. T Close, Esq	Dr Robertson Edward J Lowe, Esq., F R.A.S , F L.S. The Rev J F M'Callan, M.A
HIS GRACE THE DUKE OF BUCCLEUCH, K.G , D.C.L., F.R.S. DUNDEE, September 4, 1867	The Right Hon. the Earl of Airlie, K T The Right Hon the Lord Kinnaird, K T Sir John Ogilvy, Bart , M P Sir Roderick I Murchison, Bart , K C.B , LL D , F R S , F G S , &c Sir David Baxter, Bart Sir David Brewster, D C L., F R.S , Principal of the University of Edinburgh James D Forbes, LL.D , F R.S , Principal of the United College of St Salvator and St. Leonard, University of St. Andrews	J Henderson, Esq., jun John Austin Lake Gloag, Esq Patrick Anderson, Esq
JOSEPH DALTON HOOKER, M D., D C.L., F R.S , F.L.S. NORWICH, August 19, 1868.	The Right Hon the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F R.S. The Rev Adam Sedgwick, M A. LL.D , F R.S , F G S , &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F R.S., F L.S., F G S. John Couch Adams, Esq , M A., D C L., F R.S., F R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq	Dr Donald Dalrymple Rev Joseph Crompton, M A. Rev Canon Hinds Howell
PROFESSOR GEORGE G STOKES, D.C L., F R.S. EXETER, August 18, 1869	The Right Hon the Earl of Devon The Right Hon Sir Stafford H Northcote, Bart., C B , M P , &c. Sir John Bowring, LL.D , F R.S William B Carpenter, M D , F R S , F L.S Robert Were Fox, Esq , F R.S W H Fox Talbot, Esq , M A , LL D , F R.S , F L.S.	Henry S Ellis, Esq , F R.A S. John C Bowring, Esq The Rev R Kirwan
PROFESSOR T. H. HUXLEY, LL.D., F.R.S , F.G.S LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D , F R.S Sir Philip de M Grey Egerton, Bart , M P The Right Hon. W E. Gladstone, D C.L., M.P S. R. Graves, Esq., M P Sir Joseph Whitworth, Bart., LL.D , D C L., F R.S. James P Joule, LL.D., D C L., F R S Joseph Mayer, Esq., F S.A., F R.G S.	Rev W Banister. Reginald Harrison, Esq Rev Henry H Higgins, M A Rev Dr A. Hume, F S.A

PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.SS.L. & E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., *Lord Justice-General of Scotland* Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.SS.L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
DR. W. B. CARPENTER, LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Earl of Chichester, Lord-Lieutenant of the County of Sussex. The Duke of Norfolk. The Right Hon. the Duke of Richmond, K.G., P.C., D.C.L. The Right Hon. the Duke of Devonshire, K.G., D.C.L., F.R.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. J. Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, LL.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S. Sir John Hawkshaw, F.R.S., F.G.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. Rev. Dr. Henry Rev. Dr. Robinson, F.R.S. Dr. Andrews, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Dr. T. Redfern. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. *Lant Carpenter*, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S.L. & E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Sir William Thomson, M.A., LL.D., D.C.L., F.R.S.L. & E. Professor Allen Thomson, M.D., LL.D., F.R.S.L. & E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S.L. & E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents.	Secretaries
MATHEMATICAL AND PHYSICAL SCIENCES.		
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1834. Edinburgh	Rev W Whewell, F R S	Prof Forbes, Prof Lloyd
SECTION A —MATHEMATICS AND PHYSICS		
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1837 Liverpool	Sir D Brewster, F R S	W S Harris, Rev Prof Powell, Prof. Stevelly
1838 Newcastle	Sir J F W Herschel, Bart., F R S	Rev Prof Chevallier, Major Sabine, Prof Stevelly
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1848 Swansea	Lord Wrottesley, F R S ...	Dr Stevelly, G G. Stokes.
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1852 Belfast .	Prof W Thomson, M A, F R S L. & E.	Prof Dixon, W J. Macquorn Rankine, Prof Stevelly, J Tyndall
1853 Hull	The Dean of Ely, F R S.	B Blaydes Haworth, J D Sollitt, Prof Stevelly, J. Welsh.
1854. Liverpool	Prof G G. Stokes, M A., Sec R.S.	J Hartnup, H. G Puckle, Prof. Stevelly, J Tyndall, J Welsh.
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1856. Cheltenham	Rev R. Walker, M A., F.R.S	C Brooke, Rev T. A Southwood, Prof Stevelly, Rev J. C Turnbull.
1857. Dublin ...	Rev. T. R. Robinson, D D, F R.S., M.R.I.A.	Prof. Curtis, Prof Hennessy, P. A. Ninnis, W J. Macquorn Rankine, Prof Stevelly
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S Smith, Prof. Tyndall.

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1860 Oxford .	Rev. B. Price, M.A , F R S ..	Rev G. C Bell, Rev T Rennison, Prof Stevelly
1861 Manchester	G B Airy, M A , D C L , F R S	Prof R B Clifton, Prof H J S Smith, Prof. Stevelly.
1862 Cambridge	Prof G G Stokes, M A , F R S	Prof R B Clifton, Prof H J S Smith, Prof Stevelly
1863 Newcastle	Prof W J Macquorn Rankine, C.E , F R S	Rev N Ferrers, Prof. Fuller, F Jenkin, Prof Stevelly, Rev C T Whitley.
1864. Bath	Prof Cayley, M A, F R S, F R A S	Prof Fuller, F Jenkin, Rev G. Buckle, Prof Stevelly
1865 Birmingham	W Spottiswoode, M A., F R S, F R A S	Rev T N Hutchinson, F Jenkin, G S Mathews, Prof H J S Smith, J M Wilson
1866 Nottingham	Prof Wheatstone, D.C.L , F.R S	Fleeming Jenkin, Prof. H. J S Smith, Rev S N Swann
1867 Dundee .	Prof Sir W Thomson, D C L, F R S	Rev G Buckle, Prof G C Foster, Prof Fuller, Prof Swan.
1868 Norwich	Prof J Tyndall, LL D , F R S	Prof G. C Foster, Rev R Harley, R B Hayward
1869 Exeter .	Prof. J J. Sylvester, LL D., F R S.	Prof G C Foster, R B Hayward, W K Clifford
1870 Liverpool	J Clerk Maxwell, M A , LL D , F R S	Prof W G Adams, W K Clifford, Prof G C Foster, Rev. W Allen Whitworth
1871 Edinburgh	Prof P G Tait, F R S E	Prof W G Adams, J T Bottomley, Prof W K Clifford, Prof. J D. Everett, Rev R Harley
1872. Brighton .	W De La Rue, D C L , F R.S .	Prof W K Clifford, J W L. Glaisher, Prof A S Herschel, G F Rodwell.
1873. Bradford ...	Prof H J S. Smith, F R S..	Prof W K Clifford, Prof Forbes, J W L. Glaisher, Prof A S Herschel
1874 Belfast . .	Rev Prof J H. Jellett, M.A , M R I A	J W L Glaisher, Prof Herschel, Randal Nixon, J Perry, G F Rodwell.
1875 Bristol .	Prof. Balfour Stewart, M A , LL D , F.R S	Prof W F Barrett, J W L Glaisher, C T Hudson, G F Rodwell
1876. Glasgow	Prof Sir W Thomson, M A , D C L., F R S	Prof W F Barrett, J T Bottomley, Prof G Forbes, J W L Glaisher, T. Muir

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford .	John Dalton, D C L , F R.S	James F W Johnston
1833. Cambridge	John Dalton, D.C L , F.R S.	Prof Miller.
1834. Edinburgh .	Dr. Hope..	Mr. Johnston, Dr Christison

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin .. .	Dr T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston
1836. Bristol .. .	Rev. Prof. Cumming	Dr. Apjohn, Dr C. Henry, W. Herapath.
1837. Liverpool. .	Michael Faraday, F.R.S.	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle...	Rev. William Whewell, F.R.S....	Prof. Miller, R. L. Pattinson, Thomas Richardson.

Date and Place.	Presidents.	Secretaries.
1839. Birmingham	Prof T Graham, F.R S	Golding Bird, M D, Dr J. B Melson
1840. Glasgow	Dr Thomas Thomson, F R S	Dr R D Thomson, Dr T Clark, Dr L Playfair
1841 Plymouth	Dr Daubeny, F R S ...	J Prideaux, Robert Hunt, W. M. Tweedy
1842 Manchester.	John Dalton, D C L, F R S	Dr L Playfair, R Hunt, J. Graham
1843 Cork	Prof Apjohn, M R I A	R Hunt, Dr. Sweeny
1844 York	Prof. T Graham, F R S	Dr R Playfair, E Solly, T H Barker.
1845 Cambridge	Rev Prof Cumming. .	R Hunt, J P. Joule, Prof. Miller, E Solly
1846. Southampton	Michael Faraday, D C L, F R S	Dr Miller, R Hunt, W Randall
1847 Oxford	Rev W V Harcourt, M A, F R S	B C Brodie, R Hunt, Prof Solly
1848 Swansea	Richard Phillips, F R S	T H Henry, R Hunt, T. Williams.
1849 Birmingham	John Percy, M D, F R S	R Hunt, G Shaw
1850 Edinburgh	Dr Christison, V P R S E .	Dr Anderson, R. Hunt, Dr Wilson
1851 Ipswich	Prof Thomas Graham, F R S	T J Pearsall, W S Ward
1852 Belfast	Thomas Andrews, M D, F R S	Dr Gladstone, Prof Hodges, Prof. Ronalds
1853 Hull	Prof J F W Johnston, M A, F.R S	H S Blundell, Prof R Hunt, T J. Pearsall
1854. Liverpool	Prof W A Miller, M D, F R S	Dr Edwards, Dr Gladstone, Dr. Price.
1855 Glasgow	Dr. Lyon Playfair, C B, F R S	Prof Frankland, Dr H E Roscoe.
1856 Cheltenham	Prof B C. Brodie, F R S.	J Horsley, P J Worsley, Prof. Voelcker
1857 Dublin	Prof Apjohn, M D, F R S, M R.I A	Dr Davy, Dr. Gladstone, Prof Sullivan
1858 Leeds	Sir J F W. Herschel, Bart D C L.	Dr Gladstone, W Odling, R Reynolds
1859 Aberdeen	Dr Lyon Playfair, C B, F R S	J S Brazier, Dr Gladstone, G D Liveing, Dr Odling
1860. Oxford	Prof B C Brodie, F R S	A Vernon Harcourt, G D Liveing, A. B Northcote
1861. Manchester	Prof W A Miller, M D, F R S	A Vernon Harcourt G D Liveing
1862. Cambridge	Prof W A Miller, M D, F R S	H W Elphinstone, W Odling, Prof. Roscoe
1863. Newcastle	Dr Alex W Williamson, F R.S	Prof Liveing, H L. Pattinson, J. C Stevenson.
1864 Bath	W Odling, M B, F R.S, F C S	A V Harcourt, Prof Liveing, R. Biggs
1865. Birmingham	Prof W A Miller, M D, V P R.S	A. V Harcourt, H Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H Bence Jones, M D, F.R S	J. H. Atherton, Prof Liveing, W. J. Russell, J White.
1867. Dundee	Prof T Anderson, M D, F R S E	A. Crum Brown, Prof G D Liveing, W J Russell
1868 Norwich	Prof E. Frankland, F R S, F.C S	Dr. A. Crum Brown, Dr. W J Russell, F Sutton
1869. Exeter	Dr H. Debus, F R.S, F C S .	Prof A Crum Brown, M D, Dr W. J. Russell, Dr Atkinson.
1870 Liverpool	Prof H E Roscoe, B A, F.R.S., F C.S	Prof A Crum Brown, M D., A. E. Fletcher, Dr W J. Russell.
1871. Edinburgh	Prof. T. Andrews, M D., F.R.S	J T Buchanan, W. N. Hartley, T. E. Thorpe
1872. Brighton ...	Dr. J. H Gladstone, F.R.S	Dr Mills, W. Chandler Roberts, Dr. W. J Russell, Dr. T Wood.
1873. Bradford ..	Prof. W. J. Russell, F R.S .	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast	Prof. A. Crum-Brown, M.D., F.R.S.E., F.C.S.	Dr T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol ...	A. G. Vernon Harcourt, M.A., F.R.S., F.C.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W Chandler Roberts, J. M. Thomson, W. A. Tilden.

Date and Place	Presidents	Secretaries.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE

COMMITTEE OF SCIENCES, III —GEOLOGY AND GEOGRAPHY

1832 Oxford	R I Murchison F R S	John Taylor
1833 Cambridge	G B Greenough F R S	W Lonsdale John Phillips
1834 Edinburgh	Prof Jameson	Prof Phillips T Jameson Torrie, Rev J Yates

SECTION C —GEOLOGY AND GEOGRAPHY

1835 Dublin	R J Griffith	Captain Portlock T J Torrie
1836 Bristol	Rev Dr Buckland F R S —*Geography* R I Murchison F R S	William Sanders S Stutchbury T J Torrie
1837 Liverpool	Rev Prof Sedgwick F R S —*Geography* G B Greenough F R S	Captain Portlock R Hunter —*Geography* Captain H M Denham R N
1838 Newcastle	C Lyell F R S V P G S —*Geography* Lord Prudhope	W C Trevelyan Capt Portlock —*Geography* Capt Washington
1839 Birmingham	Rev Dr Buckland F R S —*Geography* G B Greenough F R S	George Lloyd M D H E Strickland Charles Darwin
1840 Glasgow	Charles Lyell F R S —*Geography* G B Greenough F R S	W J Hamilton D Milne Hugh Murray H E Strickland John Scoular M D
1841 Plymouth	H T De la Beche F R S	W J Hamilton Edward Moore M D R Hutton
1842 Manchester	R I Murchison F R S	E W Binney R Hutton Dr R Lloyd H E Strickland
1843 Cork	Richard J Griffith F R S M R I A	Francis M Jennings H E Strickland
1844 York	Henry Warburton M P Pres Geol Soc	Prof Ansted E H Bunbury
1845 Cambridge	Rev Prof Sedgwick M A F R S	Rev J C Cumming A C Ramsay Rev W Thorp
1846 Southampton	Leonard Horner F R S —*Geography* G B Greenough F R S	Robert A Austen J H Norton M D, Prof Oldham —*Geography* Dr C T Beke
1847 Oxford	Very Rev Dr Buckland F R S	Prof Ansted Prof Oldham A C Ramsay J Ruskin
1848 Swansea	Sir H T De la Beche C B F R S	Starling Benson Prof Oldham Prof Ramsay
1849 Birmingham	Sir Charles Lyell F R S F G S	J Beete Jukes Prof Oldham Prof A C Ramsay
1850 Edinburgh *	Sir Roderick I Murchison F R S	A Keith Johnston Hugh Miller Prof Nicol

SECTION C (*continued*) —GEOLOGY

1851 Ipswich	William Hopkins M A F R S	C J F Bunbury, G W Ormerod Searles Wood
1852 Belfast	Lieut Col Portlock R E , F R S	James Bryce James MacAdam Prof M Coy Prof Nicol
1853 Hull	Prof Sedgwick F R S	Prof Harkness William Lawton
1854 Liverpool	Prof Edward Forbes F R S	John Cunningham Prof Harkness G W Ormerod, J W. Woodall

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* At a Meeting of the General Committee held in 1850, it was resolved 'That the subject of Geography be separated from Geology and combined with Ethnology to constitute a separate Section under the title of the Geographical and Ethnological Section for Presidents and Secretaries of which see page xxxvii

Date and Place	Presidents	Secretaries
1855 Glasgow	Sir R I Murchison F R S	James Bryce Prof Harkness Prof Nicol
1856 Cheltenham	Prof A C Ramsay F R S	Rev P B Brodie Rev R Hepworth Edward Hull J Scougall T Wright
1857 Dublin	The Lord Talbot de Malahide	Prof Harkness Gilbert Sanders Robert H Scott
1858 Leeds	William Hopkins M A LL D F R S	Prof Nicol H C Sorby F W Shaw
1859 Aberdeen	Sir Charles Lyell LL D D C L F R S	Prof Harkness Rev J Longmuir H C Sorby
1860 Oxford	Rev Prof Sedgwick LL D F R S F G S	Prof Harkness Edward Hull Capt Woodall
1861 Manchester	Sir R I Murchison D C L LL D F R S &c	Prof Harkness Edward Hull T Rupert Jones G W Ormerod
1862 Cambridge	J Beete Jukes M A F R S	Lucas Barrett Prof T Rupert Jones, H C Sorby
1863 Newcastle	Prof Warington W Smyth F R S F G S	E F Boyd John Daglish, H C Sorby Thomas Sopwith
1864 Bath	Prof J Phillips LL D F R S F G S	W B Dawkins J Johnston H C Sorby W Pengelly
1865 Birmingham	Sir R I Murchison Bart K C B	Rev P B Brodie J Jones Rev E Myers H C Sorby W Pengelly
1866 Nottingham	Prof A C Ramsay LL D F R S	R Etheridge W Pengelly T Wilson G H Wright
1867 Dundee	Archibald Geikie F R S F G S	Edward Hull W Pengelly Henry Woodward
1868 Norwich	R A C Godwin Austen F R S F G S	Rev O Fisher Rev J Gunn W Pengelly Rev H H Winwood
1869 Exeter	Prof R Harkness F R S F G S	W Pengelly W Boyd Dawkins Rev H H Winwood
1870 Liverpool	Sir Philip de M Grey Egerton Bart M P F R S	W Pengelly Rev H H Winwood, W Boyd Dawkins G H Morton
1871 Edinburgh	Prof A Geikie F R S F G S	R Etheridge J Geikie J McKenny Hughes L C Miall
1872 Brighton	R A C Godwin Austen F R S	L C Miall George Scott William Topley Henry Woodward
1873 Bradford	Prof J Phillips D C L F R S F G S	L C Miall R H Tiddeman W Topley
1874 Belfast	Prof Hull M A, F R S, F G S	F Drew L C Miall R G Symes, R H Tiddeman
1875 Bristol	Dr Thomas Wright F R S E F G S	L C Miall E B Tawney W Topley,
1876 Glasgow	Prof John Young M D	J Armstrong F W Rudler W Topley

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV — ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY

1832 Oxford	Rev P B Duncan, F G S	Rev Prof J S Henslow
1833 Cambridge*	Rev W L P Garnons, F L S	C C Babington D Don
1834 Edinburgh	Prof Graham	W Yarrell, Prof Burnett

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* At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p xxxvi

SECTION D —ZOOLOGY AND BOTANY

Date and Place	Presidents	Secretaries
1835 Dublin	Dr Allman	J Curtis Dr Litton
1836 Bristol	Rev Prof Henslow	J Curtis Prof Don Dr Riley S Rootsey
1837 Liverpool	W S MacLeay	C C Babington Rev L Jenyns W Swainson
1838 Newcastle	Sir W Jardine Bart	J E Gray Prof Jones R Owen Dr Richardson
1839 Birmingham	Prof Owen F R S	E Forbes W Ick R Patterson
1840 Glasgow	Sir W J Hooker LL D	Prof W Couper E Forbes R Patterson
1841 Plymouth	John Richardson M D F R S	J Couch Dr Lankester R Patterson
1842 Manchester	Hon and Very Rev W Herbert LL D F L S	Dr Lankester R Patterson J A Turner
1843 Cork	William Thompson F L S	G J Allman Dr Lankester R Patterson
1844 York	Very Rev The Dean of Manchester	Prof Allman H Goodsir Dr King Dr Lankester
1845 Cambridge	Rev Prof Henslow F L S	Dr Lankester T V Wollaston
1846 Southampton	Sir J Richardson M D F R S	Dr Lankester T V Wollaston H Wooldridge
1847 Oxford	H E Strickland M A F R S	Dr Lankester Dr Melville T V Wollaston

SECTION D (*continued*) —ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine see p xxxvii]

Date and Place	Presidents	Secretaries
1848 Swansea	L W Dillwyn F R S	Dr R Wilbraham Falconer A Henfrey Dr Lankester
1849 Birmingham	William Spence F R S	Dr Lankester Dr Russell
1850 Edinburgh	Prof Goodsir F R S L & E	Prof J H Bennett M D Dr Lankester Dr Douglas Maclagan
1851 Ipswich	Rev Prof Henslow M A F R S	Prof Allman F W Johnston Dr E Lankester
1852 Belfast	W Ogilby	Dr Dickie George C Hyndman Dr Edwin Lankester
1853 Hull	C C Babington M A F R S	Robert Harrison Dr E Lankester
1854 Liverpool	Prof Balfour M D F R S	Isaac Byerley Dr E Lankester
1855 Glasgow	Rev Dr Fleeming F R S E	William Keddie Dr Lankester
1856 Cheltenham	Thomas Bell F R S Pres L S	Dr J Abercrombie Prof Buckman Dr Lankester
1857 Dublin	Prof W H Harvey M D F R S	Prof J R Kinahan Dr E Lankester, Robert Patterson Dr W E Steele
1858 Leeds	C C Babington M A F R S	Henry Denny Dr Heaton Dr E Lankester Dr E Perceval Wright
1859 Aberdeen	Sir W Jardine Bart. F R S E.	Prof Dickie M D Dr E Lankester Dr Ogilvy
1860 Oxford	Rev Prof Henslow F L S	W S Church Dr E Lankester P L Sclater Dr E Perceval Wright
1861 Manchester	Prof C C Babington F R S	Dr T Alcock Dr E Lankester, Dr P L Sclater Dr E P Wright
1862 Cambridge	Prof Huxley F R S	Alfred Newton Dr E P Wright.
1863 Newcastle	Prof Balfour, M D, F R S	Dr E Charlton A Newton Rev H B Tristram Dr E P Wright.
1864 Bath	Dr John E Gray F R S	H B Brady, C E Broom, H T Stainton Dr E P Wright
1865 Birmingham	T Thomson, M D, F R S	Dr J Anthony, Rev C Clarke, Rev H B Tristram, Dr E P Wright

SECTION D (*continued*) —BIOLOGY *

Date and Place	Presidents	Secretaries
1866 Nottingham	Prof Huxley LLD F R S—*Physiological Dep* Prof Humphry M D F R S *Anthropological Dep* Alfred R Wallace F R G S	Dr J Beddard W Felkin Rev H B Tristram W Turner E B Tylor Dr E P Wright
1867 Dundee	Prof Sharpey M D Sec R S—*Dep of Zool and Bot* George Busk M D F R S	C Spence Bate Dr S Cobbold Dr M Foster H T Stainton Rev H B Tristram Prof W Turner
1868 Norwich	Rev M J Berkeley F L S—*Dep of Physiology* W H Flower F R S	Dr T S Cobbold G W Firth Dr M Foster Prof Lawson H T Stainton Rev Dr H B Tristram Dr E P Wright
1869 Exeter	George Busk F R S F L S—*Dep of Bot and Zool* C Spence Bate F R S—*Dep of Ethno* E B Tylor	Dr T S Cobbold Prof M Foster M D E Ray Lankester Professor Lawson H T Stainton Rev H B Tristram
1870 Liverpool	Prof G Rolleston M A M D F R S F L S *Dep Anat and Physiol* Prof M Foster M D F L S—*Dep of Ethno* J Evans F R S	Dr T S Cobbold Sebastian Evans Prof Lawson Thos J Moore H T Stainton Rev H B Tristram C Staniland Wake E Ray Lankester
1871 Edinburgh	Prof Allen Thomson M D F R S—*Dep of Bot and Zool* Prof Wyville Thomson F R S—*Dep of Anthropol* Prof W Turner M D	Dr T R Fraser Dr Arthur Gamgee E Ray Lankester Prof Lawson H T Stainton C Staniland Wake Dr W Rutherford Dr Kelburne King
1872 Brighton	Sir John Lubbock Bart F R S—*Dep of Anat and Physiol* Dr Burdon Sanderson F R S—*Dep of Anthropol* Col A Lane Fox F G S	Prof Thiselton Dyer H T Stainton Prof Lawson F W Rudler J H Lamprey Dr Gamgee E Ray Lankester Dr Pye Smith
1873 Bradford	Prof Allman F R S *Dep of Anat and Physiol* Prof Rutherford M D—*Dep of Anthropol* Dr Beddoe F R S	Prof Thiselton Dyer Prof Lawson R M Lachlan Dr Pye Smith E Ray Lankester F W Rudler J H Lamprey
1874 Belfast	Prof Redfern M D—*Dep of Zool and Bot* Dr Hooker C B Pres R S—*Dep of Anthrop* Sir W R Wilde M D	W T Thiselton Dyer R O Cunningham Dr J J Charles Dr P H Pye Smith J J Murphy F W Rudler
1875 Bristol	P L Sclater F R S *Dep of Anat and Physiol* Prof Cleland M D F R S—*Dep of Anthropol* Prof Rolleston M D F R S	E R Alston Dr McKendrick Prof W R M Nab Dr Martyn F W Rudler Dr P H Pye Smith Dr W Spencer
1876 Glasgow	A Russel Wallace F R G S F L S *Dep of Zool and Bot* Prof A Newton M A F R S *Dep of Anat and Physiol* Dr J G McKendrick F R S E	E R Alston Hyde Clarke Dr Knox Prof W R M Nab Dr Muirhead Prof Morrison Watson

ANATOMICAL AND PHYSIOLOGICAL SCIENCES

COMMITTEE OF SCIENCES, V —ANATOMY AND PHYSIOLOGY

1833 Cambridge	Dr Haviland	Dr Bond Mr Paget
1834 Edinburgh	Dr Abercrombie	Dr Roget Dr William Thomson

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* At a Meeting of the General Committee in 1865 it was resolved — That the title of Section D be changed to Biology and That for the word Subsection in the rules for conducting the business of the Sections, the word Department be substituted

SECTION F (UNTIL 1847)—ANATOMY AND MEDICINE

Date and Place	Presidents	Secretaries
1835 Dublin	Dr Pritchard	Dr Harrison Dr Hart
1836 Bristol	Dr Roget F R S	Dr Symonds
1837 Liverpool	Prof W Clark M D	Dr J Carson jun James Long Dr J R W Vose
1838 Newcastle	T E Headlam M D	T M Greenhow Dr J R W Vose
1839 Birmingham	John Yelloly M D F R S	Dr G O Rees F Ryland
1840 Glasgow	James Watson M D	Dr J Brown Prof Couper Prof Reid
1841 Plymouth	P M Roget M D Sec R S	Dr J Butter J Fuge Dr R S Sargent
1842 Manchester	Edward Holme M D F L S	Dr Chaytor Dr R S Sargent
1843 Cork	Sir James Pitcairn M D	Dr John Popham Dr R S Sargent
1844 York	J C Pritchard M D	I Erichsen Dr R S Sargent

SECTION E—PHYSIOLOGY

Date and Place	Presidents	Secretaries
1845 Cambridge	Prof J Haviland M D	Dr R S Sargent Dr Webster
1846 Southampton	Prof Owen M D F R S	C P Keele, Dr Laycock Dr Sargent
1847 Oxford*	Prof Ogle M D F R S	Dr Thomas K Chambers W P Ormerod

PHYSIOLOGICAL SUBSECTIONS OF SECTION D

Date and Place	Presidents	Secretaries
1850 Edinburgh	Prof Bennett M D F R S E	
1855 Glasgow	Prof Allen Thomson F R S	Prof J H Corbett Dr J Struthers
1857 Dublin	Prof R Harrison M D	Dr R D Lyons Prof Redfern
1858 Leeds	Sir Benjamin Brodie Bart F R S	C G Wheelhouse
1859 Aberdeen	Prof Sharpey M D Sec R S	Prof Bennett Prof Redfern
1860 Oxford	Prof G Rolleston M D F L S	Dr R M Donnell Dr Edward Smith
1861 Manchester	Dr John Davy F R S L & E	Dr W Roberts Dr Edward Smith
1862 Cambridge	C E Paget M D	G F Helm Dr Edward Smith
1863 Newcastle	Prof Rolleston M D F R S	Dr D Embleton Dr W Turner
1864 Bath	Dr Edward Smith LL D F R S	J S Bartrum Dr W Turner
1865 Birmingham†	Prof Acland M D LL D F R S	Dr A Fleming Dr P Heslop Oliver Pembleton Dr W Turner

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES

[For Presidents and Secretaries for Geography previous to 1851 see Section C p xxxiii]

ETHNOLOGICAL SUBSECTIONS OF SECTION D

Date and Place	Presidents	Secretaries
1846 Southampton	Dr Pritchard	Dr King
1847 Oxford	Prof H H Wilson M A	Prof Buckley
1848 Swansea		G Grant Francis
1849 Birmingham		Dr R G Latham
1850 Edinburgh	Vice Admiral Sir A Malcolm	Daniel Wilson

SECTION E —GEOGRAPHY AND ETHNOLOGY

Date and Place	Presidents	Secretaries
1851 Ipswich	Sir R I Murchison, F R S Pres R G S	R Cull, Rev J W Donaldson, Dr Norton Shaw
1852 Belfast	Col Chesney R A D C L F R S	R Cull R MacAdam, Dr Norton Shaw

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* By direction of the General Committee at Oxford Sections D and E were incorporated under the name of "Section D—Zoology and Botany including Physiology" (see p xxxv) The Section being then vacant was assigned in 1851 to Geography

† *Vide* note on page xxxvi

Date and Place.	Presidents	Secretaries
1853 Hull	R G Latham, M D, F R S	R Cull, Rev H W Kemp, Dr Norton Shaw
1854 Liverpool.	Sir R I Murchison, D C L, F R S	Richard Cull, Rev H Higgins, Dr. Ihne, Dr Norton Shaw
1855 Glasgow	Sir J Richardson, M D, F R S	Dr W G Blackie, R Cull, Dr Norton Shaw
1856 Cheltenham	Col Sir H C Rawlinson, K C B	R Cull, F D Hartland, W H. Rumsey, Dr Norton Shaw
1857. Dublin	Rev Dr J Henthawn Todd, Pres R I A	R Cull, S Ferguson, Dr. R. R Madden, Dr Norton Shaw
1858 Leeds	Sir R I Murchison, G C St S, F R S	R Cull, Francis Galton P O'Callaghan, Dr Norton Shaw, Thomas Wright.
1859 Aberdeen ..	Rear-Admiral Sir James Clerk Ross, D C L, F R S	Richard Cull, Professor Geddes, Dr. Norton Shaw
1860 Oxford	Sir R I Murchison, D C L, F R S	Capt Burrows, Dr J Hunt, Dr C Lempriere, Dr Norton Shaw
1861 Manchester	John Crawfurd, F R S	Dr J Hunt, J Kingsley, Dr Norton Shaw, W Spottiswoode
1862 Cambridge	Francis Galton, F R S	J W Clarke, Rev J. Glover, Dr. Hunt, Dr Norton Shaw, T Wright.
1863. Newcastle	Sir R I Murchison, K C B, F R S	C Carter Blake, Hume Greenfield, C R Markham, R S Watson
1864 Bath	Sir R I Murchison, K C B, F R S	H W Bates, C R Markham, Capt R. M Murchison, T Wright
1865 Birmingham	Major-General Sir H Rawlinson, M P, K C B, F R S	H W Bates, S Evans, G Jabet, C R Markham, Thomas Wright.
1866 Nottingham	Sir Charles Nicholson, Bart, LL D	H W Bates, Rev E T Cusins, R H Major, Clements R Markham, D W Nash, T Wright
1867 Dundee	Sir Samuel Baker, F R G S	H W Bates, Cyril Graham, C R Markham, S J Mackie, R Sturrock.
1868. Norwich ..	Capt G H Richards, R.N., F R S	T Baines, H W Bates, C R. Markham, T Wright

SECTION E (*continued*) — GEOGRAPHY

Date and Place.	Presidents	Secretaries
1869. Exeter	Sir Bartle Frere, K C B, LL D, F R G S	H W Bates, Clements R Markham, J H Thomas.
1870. Liverpool	Sir R I Murchison, Bt, K C B, LL D, D C L, F R S, F G S	H W Bates, David Buxton, Albert J Mott, Clements R Markham
1871. Edinburgh	Colonel Yule, C.B, F.R G S	Clements R Markham, A Buchan, J H Thomas, A Keith Johnston
1872 Brighton	Francis Galton, F R S	H W Bates, A Keith Johnston, Rev. J Newton, J H Thomas
1873 Bradford ..	Sir Rutherford Alcock, K C B	H W Bates, A. Keith Johnston, Clements R. Markham.
1874 Belfast	Major Wilson, R E, F R S, F R G S	E G Ravenstein, E C. Rye, J. H Thomas
1875 Bristol ..	Lieut -General Strachey, R E., C S I, F R S, F.R G S, F L S, F G S	H W Bates, E C Rye, F F Tuckett
1876 Glasgow	Capt Evans, C.B, F R S	H W Bates, E C Rye, R. Oliphant Wood.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

Date and Place.	Presidents	Secretaries
1833 Cambridge	Prof. Babbage, F.R.S.	J E. Drinkwater
1834 Edinburgh	Sir Charles Lemon, Bart.	Dr. Cleland, C Hope Maclean.

Date and Place	Presidents	Secretaries
	SECTION F —STATISTICS	
1835 Dublin	Charles Babbage FRS	W Greg Prof Longfield
1836 Bristol	Sir Charles Lemon Bart FRS	Rev J F Bromby C B Fripp James Heywood
1837 Liverpool	Rt Hon Lord Sandon	W R Greg W Langton Dr W C Tayler
1838 Newcastle	Colonel Sykes FRS	W Cargill J Heywood W R Wood
1839 Birmingham	Henry Hallam FRS	F Clarke R W Rawson Dr W C Tayler
1840 Glasgow	Rt Hon Lord Sandon MP FRS	C R Baird Prof Ramsay R W Rawson
1841 Plymouth	Lieut Col Sykes FRS	Rev Dr Byrth Rev R Luney R W Rawson
1842 Manchester	G W Wood MP FLS	Rev R Luney G W Ormerod Dr W C Tayler
1843 Cork	Sir C Lemon Bart MP	Dr D Bullen Dr W Cooke Tayler
1844 York	Lieut Col Sykes FRS FLS	J Fletcher J Heywood Dr Laycock
1845 Cambridge	Rt Hon The Earl Fitzwilliam	J Fletcher W Cooke Tayler LLD
1846 Southampton	G R Porter FRS	J Fletcher F G P Neison Dr W C Tayler Rev T L Shapcott
1847 Oxford	Travers Twiss DCL FRS	Rev W H Cox J J Danson F G P Neison
1848 Swansea	J H Vivian MP FRS	J Fletcher Capt R Shortrede
1849 Birmingham	Rt Hon Lord Lyttelton	Dr Finch Prof Hancock F G P Neison
1850 Edinburgh	Very Rev Dr John Lee VPRSE	Prof Hancock J Fletcher Dr J Stark
1851 Ipswich	Sir John P Boileau Bart	J Fletcher Prof Hancock
1852 Belfast	His Grace the Archbishop of Dublin	Prof Hancock Prof Ingram James MacAdam Jun
1853 Hull	James Heywood MP FRS	Edward Cheshire William Newmarch
1854 Liverpool	Thomas Tooke FRS	E Cheshire J T Danson Dr W H Duncan W Newmarch
1855 Glasgow	R Monckton Milnes MP	J A Campbell E Cheshire W Newmarch Prof R H Walsh
	SECTION F (continued) —ECONOMIC SCIENCE AND STATISTICS	
1856 Cheltenham	Rt Hon Lord Stanley MP	Rev C H Bromby E Cheshire Dr W N Hancock W Newmarch W M Tartt
1857 Dublin	His Grace the Archbishop of Dublin MRIA	Prof Cairnes Dr H D Hutton W Newmarch
1858 Leeds	Edward Baines	T B Baines Prof Cairnes S Brown Capt Fishbourne Dr J Strang
1859 Aberdeen	Col Sykes MP FRS	Prof Cairns Edmund Macrory A M Smith Dr John Strang
1860 Oxford	Nassau W Senior MA	Edmund Macrory W Newmarch Rev Prof J E T Rogers
1861 Manchester	William Newmarch FRS	David Chadwick Prof R C Christie E Macrory Rev Prof J E T Rogers
1862 Cambridge	Edwin Chadwick CB	H D Macleod, Edmund Macrory
1863 Newcastle	William Tite MP FRS	T Doubleday Edmund Macrory Frederick Purdy James Potts
1864 Bath	William Farr MD DCL FRS	E. Macrory, E T Payne, F Purdy
1865 Birmingham	Rt. Hon Lord Stanley, LLD MP	G J D Goodman G J Johnston, E Macrory

Date and Place	Presidents	Secretaries
1866 Nottingham	Prof J E T Rogers	R Birkin Jun Prof Leone Levi E Macrory
1867 Dundee	M E Grant Duff M P	Prof Leone Levi E Macrory A J Warden
1868 Norwich	Samuel Brown Pres Instit Actuaries	Rev W C Davie Prof Leone Levi
1869 Exeter	Rt Hon Sir Stafford H Northcote Bart C B M P	Edmund Macrory Frederick Purdy Charles T D Acland
1870 Liverpool	Prof W Stanley Jevons M A	Chas R Dudley Baxter E Macrory J Miles Moss
1871 Edinburgh	Rt Hon Lord Neaves	J G Fitch James Meikle
1872 Brighton	Prof Henry Fawcett M P	J G Fitch Barclay Phillips
1873 Bradford	Rt Hon W E Forster M P	J G Fitch Swire Smith
1874 Belfast	Lord O Hagan	Prof Donnell Frank P Fellows Hans Mac Mordie
1875 Bristol	James Heywood M A F R S Pres S S	F P Fellows T G P Hallett E Macrory
1876 Glasgow	Sir George Campbell K C S I M P	A M Neel Caird T G P Hallett Dr W Neilson Hancock Dr W Jack

MECHANICAL SCIENCE

SECTION G —MECHANICAL SCIENCE

1836 Bristol	Davies Gilbert D C L F R S	T G Bunt G T Clark W West
1837 Liverpool	Rev Dr Robinson	Charles Vignoles Thomas Webster
1838 Newcastle	Charles Babbage F R S	R Hawthorn C Vignoles T Webster
1839 Birmingham	Prof Willis F R S and Robert Stephenson	W Carpmael William Hawkes Thomas Webster
1840 Glasgow	Sir John Robinson	J Scott Russell J Thomson J Tod C Vignoles
1841 Plymouth	John Taylor F R S	Henry Chatfield Thomas Webster
1842 Manchester	Rev Prof Willis F R S	J F Bateman J Scott Russell J Thomson Charles Vignoles
1843 Cork	Prof J Macneill M R I A	James Thomson Robert Mallet
1844 York	John Taylor F R S	Charles Vignoles Thomas Webster
1845 Cambridge	George Rennie F R S	Rev W T Kingsley
1846 Southampton	Rev Prof Willis M A F R S	William Betts jun Charles Manby
1847 Oxford	Rev Prof Walker M A F R S	J Glynn R A Le Mesurier
1848 Swansea	Rev Prof Walker M A F R S	R A Le Mesurier W P Struvé
1849 Birmingham	Robert Stephenson M P F R.S	Charles Manby W P Marshall
1850 Edinburgh	Rev Dr Robinson	Dr Lees David Stephenson
1851 Ipswich	William Cubitt F R S	John Head Charles Manby
1852. Belfast	John Walker C E LL D F R S	John F Bateman C B Hancock Charles Manby James Thomson
1853 Hull	William Fairbairn C E F R S	James Oldham J Thomson W Sykes Ward
1854 Liverpool	John Scott Russell F R S	John Grantham J Oldham J Thomson
1855 Glasgow	W J Macquorn Rankine, C E F R S	L Hill Jun , William Ramsay, J Thomson
1856 Cheltenham	George Rennie F R S	C Atherton B Jones jun , H M. Jeffery
1857 Dublin	The Right Hon The Earl of Rosse F R S	Prof Downing W T Doyne A Tate, James Thomson Henry Wright
1858 Leeds	William Fairbairn F R S	J C Dennis J Dixon H Wright
1859 Aberdeen	Rev Prof Willis, M A F R.S	R Abernethy, P Le Neve Foster H Wright.
1860 Oxford	Prof W J Macquorn Rankine, LL.D., F R S	P Le Neve Foster Rev F Harrison Henry Wright

Date and Place	Presidents	Secretaries
1861 Manchester	J F Bateman C E F R S	P Le Neve Foster John Robinson H Wright
1862 Cambridge	William Fairbairn LL D F R S	W M Fawcett P Le Neve Foster
1863 Newcastle	Rev Prof Willis M A F R S	P Le Neve Foster P Westmacott J F Spencer
1864 Bath	J Hawkshaw F R S	P Le Neve Foster Robert Pitt
1865 Birmingham	Sir W G Armstrong LL D F R S	P Le Neve Foster Henry Lea W P Marshall Walter May
1866 Nottingham	Thomas Hawksley V P Inst C E F G S	P Le Neve Foster J F Iselin M A Tarbotton
1867 Dundee	Prof W J Macquorn Rankine LL D F R S	P Le Neve Foster John P Smith W W Urquhart
1868 Norwich	G P Bidder C E F R G S	P Le Neve Foster J F Iselin C Manby W Smith
1869 Exeter	C W Siemens F R S	P Le Neve Foster H Bauerman
1870 Liverpool	Chas B Vignoles C E F R S	H Bauerman P Le Neve Foster, T King J N Shoolbred
1871 Edinburgh	Prof Fleeming Jenkin F R S	H Bauerman Alexander Leslie J P Smith
1872 Brighton	F J Bramwell C E	H M Brunel P Le Neve Foster J G Gamble J N Shoolbred
1873 Bradford	W H Barlow F R S	Crawford Barlow H Bauerman E H Carbutt J C Hawkshaw J N Shoolbred
1874 Belfast	Prof James Thomson LL D C E F R S E	A T Atchison J N Shoolbred John Smyth jun
1875 Bristol	W Froude C E M A F R S	W R Browne H M Brunel J G Gamble, J N Shoolbred
1876 Glasgow	C W Merrifield F R S	W Bottomley jun W J Millar J N Shoolbred J P Smith

List of Evening Lectures

Date and Place	Lecturer	Subject of Discourse
1842 Manchester	Charles Vignoles F R S	The Principles and Construction of Atmospheric Railways
	Sir M I Brunel	The Thames Tunnel
	R I Murchison	The Geology of Russia
1843 Cork	Prof Owen M D F R S	The Dinornis of New Zealand
	Prof E Forbes F R S	The Distribution of Animal Life in the Ægean Sea
	Dr Robinson	The Earl of Rosse's Telescope
1844 York	Charles Lyell F R S	Geology of North America
	Dr Falconer F R S	The Gigantic Tortoise of the Siwalik Hills in India
1845 Cambridge	G B Airy F R S Astron Royal	Progress of Terrestrial Magnetism
	R I Murchison F R S	Geology of Russia
1846 Southampton	Prof Owen M D F R S	Fossil Mammalia of the British Isles
	Charles Lyell F R S	Valley and Delta of the Mississippi
1846 Southampton	W R Grove F R S	Properties of the Explosive substance discovered by Dr Schönbein, also some Researches of his own on the Decomposition of Water by Heat
1847 Oxford	Rev Prof B Powell, F R S	Shooting stars
	Prof M Faraday, F R S	Magnetic and Diamagnetic Phenomena
	Hugh E Strickland, F G S.	The Dodo (*Didus ineptus*)

Date and Place	Lecturer	Subject of Discourse
1848 Swansea	John Percy M D F R S	Metallurgical operations of Swansea and its neighbourhood
	W Carpenter M D F R S	Recent Microscopical Discoveries
1849 Birmingham	Dr Faraday F R S	Mr Gassiot's Battery
	Rev Prof Willis M A F R S	Transit of different Weights with varying velocities on Railways
1850 Edinburgh	Prof J H Bennett M D F R S E	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition
	Dr Mantell F R S	Extinct Birds of New Zealand
1851 Ipswich	Prof R Owen M D F R S	Distinction between Plants and Animals and their changes of Form
	G B Airy F R S Astron Royal	Total Solar Eclipse of July 28 1851
1852 Belfast	Prof G G Stokes D C L F R S	Recent discoveries in the properties of Light
	Colonel Portlock R E F R S	Recent discovery of Rock salt at Carrickfergus and geological and practical considerations connected with it
1853 Hull	Prof J Phillips LL D F R S F G S	Some peculiar phenomena in the Geology and Physical Geography of Yorkshire
	Robert Hunt F R S	The present state of Photography
1854 Liverpool	Prof R Owen M D F R S	Anthropomorphous Apes
	Col E Sabine V P R S	Progress of researches in Terrestrial Magnetism
1855 Glasgow	Dr W B Carpenter F R S	Characters of Species
	Lieut Col H Rawlinson	Assyrian and Babylonian Antiquities and Ethnology
1856 Cheltenham	Col Sir H Rawlinson	Recent discoveries in Assyria and Babylonia with the results of Cuneiform research up to the present time
	W R Grove F R S	Correlation of Physical Forces
1857 Dublin	Prof W Thomson F R S	The Atlantic Telegraph
	Rev Dr Livingstone D C L	Recent discoveries in Africa
1858 Leeds	Prof J Phillips LL D F R S	The Ironstones of Yorkshire
	Prof R Owen M D F R S	The Fossil Mammalia of Australia
1859 Aberdeen	Sir R I Murchison D C L	Geology of the Northern Highlands
	Rev Dr Robinson F R S	Electrical Discharges in highly rarefied Media
1860 Oxford	Rev Prof Walker F R S	Physical Constitution of the Sun
	Captain Sherard Osborn R N	Arctic Discovery
1861 Manchester	Prof W A Miller M A F R S	Spectrum Analysis
	G B Airy F R S Astron Roy	The late Eclipse of the Sun
1862 Cambridge	Prof Tyndall LL D F R S	The Forms and Action of Water
	Prof Odling F R S	Organic Chemistry
1863 Newcastle on Tyne	Prof Williamson F R S	The Chemistry of the Galvanic Battery considered in relation to Dynamics
1863 Newcastle on Tyne	James Glaisher F R S	The Balloon Ascents made for the British Association
1864 Bath	Prof Roscoe, F R S	The Chemical Action of Light
	Dr Livingstone, F R S	Recent Travels in Africa
1865 Birmingham	J Beete Jukes, F R S	Probabilities as to the position and extent of the Coal measures beneath the red rocks of the Midland Counties
1866 Nottingham	William Huggins, F R S	The results of Spectrum Analysis applied to Heavenly Bodies
	Dr J D Hooker, F R S	Insular Floras

Date and Place	Lecturer	Subject of Discourse
1867 Dundee	Archibald Geikie F R S	The Geological origin of the present Scenery of Scotland
	Alexander Herschel F R A S	The present state of knowledge regarding Meteors and Meteorites
1868 Norwich	J Fergusson F R S	Archæology of the early Buddhist Monuments
	Dr W Odling F R S	Reverse Chemical Actions
1869 Exeter	Prof J Phillips LL D F R S	Vesuvius
	J Norman Lockyer F R S	The Physical Constitution of the Stars and Nebulæ
1870 Liverpool	Prof J Tyndall LL D F R S	The Scientific Use of the Imagination
	Prof W J Macquorn Rankine, LL D F R S	Stream lines and Waves in connexion with Naval Architecture
1871 Edinburgh	F A Abel F R S	Some recent investigations and applications of Explosive Agents
	E B Tylor F R S	The Relation of Primitive to Modern Civilization
1872 Brighton	Prof P Martin Duncan M D F R S	Insect Metamorphosis
	Prof W K Clifford	The Aims and Instruments of Scientific Thought
1873 Bradford	Prof W C Williamson F R S	Coal and Coal Plants
	Prof Clerk Maxwell F R S	Molecules
1874 Belfast	Sir John Lubbock Bart. M P F R S	Common Wild Flowers considered in relation to Insects
	Prof Huxley F R S	The Hypothesis that Animals are Automata and its History
1875 Bristol	William Spottiswoode LL.D F R S	The Colours of Polarized Light
	F J Bramwell F R S	Railway Safety Appliances
1876 Glasgow	Prof Tait F R S E	Force
	Sir Wyville Thomson F R S	The Challenger Expedition

Lectures to the Operative Classes

1867 Dundee	Prof J Tyndall LL D F R S	Matter and Force
1868 Norwich	Prof Huxley LL D F R S	A piece of Chalk
1869 Exeter	Prof Miller M D F R S	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum
1870 Liverpool	Sir John Lubbock Bart M P F R S	Savages
1872 Brighton	William Spottiswoode LL D F R S	Sunshine Sea and Sky
1873 Bradford	C W Siemens D C L F R S	Fuel
1874 Belfast	Professor Odling F R S	The Discovery of Oxygen
1875 Bristol	Dr W B Carpenter F R S	A piece of Limestone
1876 Glasgow	Commander Cameron C B R N	A Journey through Africa

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831 Sept 27	York	The Earl Fitzwilliam D C L		
1832 June 19	Oxford	The Rev W Buckland F R S		
1833 June 25	Cambridge	The Rev A Sedgwick F R S		
1834 Sept 8	Edinburgh	Sir T M Brisbane D C L		
1835 Aug 10	Dublin	The Rev Provost Lloyd LL D		
1836 Aug 22	Bristol	The Marquis of Lansdowne		
1837 Sept 11	Liverpool	The Earl of Burlington F R S		
1838 Aug 10	Newcastle on Tyne	The Duke of Northumberland		
1839 Aug 26	Birmingham	The Rev W Vernon Harcourt		
1840 Sept 17	Glasgow	The Marquis of Breadalbane		
1841 July 20	Plymouth	The Rev W Whewell F R S	169	65
1842 June 23	Manchester	The Lord Francis Egerton	303	169
1843 Aug 17	Cork	The Earl of Rosse F R S	109	28
1844 Sept 26	York	The Rev G Peacock D D	226	150
1845 June 19	Cambridge	Sir John F W Herschel Bart	313	36
1846 Sept 10	Southampton	Sir Roderick I Murchison Bart	241	10
1847 June 23	Oxford	Sir Robert H Inglis Bart	314	18
1848 Aug 9	Swansea	The Marquis of Northampton	149	3
1849 Sept 12	Birmingham	The Rev T R Robinson D D	227	12
1850 July 21	Edinburgh	Sir David Brewster K H	235	9
1851 July 2	Ipswich	G B Airy Esq Astron Royal	172	8
1852 Sept 1	Belfast	Lieut General Sabine F R S	164	10
1853 Sept 3	Hull	William Hopkins Esq F R S	141	13
1854 Sept 20	Liverpool	The Earl of Harrowby F R S	238	23
1855 Sept 12	Glasgow	The Duke of Argyll F R S	194	33
1856 Aug 6	Cheltenham	Prof C G B Daubeny M D	182	14
1857 Aug 26	Dublin	The Rev Humphrey Lloyd D D	236	15
1858 Sept 22	Leeds	Richard Owen M D D C L	222	42
1859 Sept 14	Aberdeen	H R H The Prince Consort	184	27
1860 June 27	Oxford	The Lord Wrottesley M A	286	21
1861 Sept 4	Manchester	William Fairbairn LL D F R S	321	113
1862 Oct 1	Cambridge	The Rev Prof Willis M A	239	15
1863 Aug 26	Newcastle on Tyne	Sir William G Armstrong C B	203	36
1864 Sept 13	Bath	Sir Charles Lyell Bart M A	287	40
1865 Sept 6	Birmingham	Prof J Phillips M A LL D	292	44
1866 Aug 22	Nottingham	William R Grove Q C F R S	207	31
1867 Sept 4	Dundee	The Duke of Buccleuch K C B	167	25
1868 Aug 19	Norwich	Dr Joseph D Hooker F R S	196	18
1869 Aug 18	Exeter	Prof G G Stokes D C L	204	21
1870 Sept 14	Liverpool	Prof T H Huxley LL D	314	39
1871 Aug 2	Edinburgh	Prof Sir W Thomson LL D	246	28
1872 Aug 14	Brighton	Dr W B Carpenter F R S	245	36
1873 Sept. 17	Bradford	Prof A. W Williamson F R S	212	27
1874, Aug 19	Belfast	Prof J Tyndall LL D F R S	162	13
1875, Aug 25	Bristol	Sir John Hawkshaw C E F R S	239	36
1876 Sept 6	Glasgow	Prof T Andrews M D F R S	221	35
1877, Aug 15	Plymouth	Prof A Thomson, M D F R S		

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting			Sums paid on Account of Grants for Scientific Purposes		
Old Annual Members.	New Annual Members	Associates	Ladies	Foreigners	Total	£	s	d	£	s	d
...	.	.	.		353						
. .		. .									
. .	..		.	.	900						
.	. .	.			1298				20	0	0
...	.	.	.	.	.				167	0	0
...	...	.	.		1350				434	14	0
...	.	. .			1840				918	14	6
. .	.		1100*		2400				956	12	2
...	.	.		34	1438				1595	11	0
...	.			40	1353				1546	16	4
46	317		60*		891				1235	10	11
75	376	33†	331*	28	1315				1449	17	8
71	185		160						1565	10	2
45	190	9†	260						981	12	8
94	22	407	172	35	1079				830	9	9
65	39	270	196	36	857				685	16	0
197	40	495	203	53	1260				208	5	4
54	25	376	197	15	929	707	0	0	275	1	8
93	33	447	237	22	1071	963	0	0	159	19	6
128	42	510	273	44	1241	1085	0	0	345	18	0
61	47	244	141	37	710	620	0	0	391	9	7
63	60	510	292	9	1108	1085	0	0	304	6	7
56	57	367	236	6	876	903	0	0	205	0	0
121	121	765	524	10	1802	1882	0	0	330	19	7
142	101	1094	543	26	2133	2311	0	0	480	16	4
104	48	412	346	9	1115	1098	0	0	734	13	9
156	120	900	569	26	2022	2015	0	0	507	15	3
111	91	710	509	13	1698	1931	0	0	618	18	2
125	179	1206	821	22	2564	2782	0	0	684	11	1
177	59	636	463	47	1689	1604	0	0	1241	7	0
184	125	1589	791	15	3139	3944	0	0	1111	5	10
150	57	433	242	25	1161	1089	0	0	1293	16	6
154	209	1704	1004	25	3335	3640	0	0	1608	3	10
182	103	1119	1058	13	2802	2965	0	0	1289	15	8
215	149	766	508	23	1997	2227	0	0	1591	7	10
218	105	960	771	11	2303	2469	0	0	1750	13	4
193	118	1163	771	7	2444	2613	0	0	1739	4	0
226	117	720	682	45‡	2004	2042	0	0	1940	0	0
229	107	678	600	17	1856	1931	0	0	1572	0	0
303	195	1103	910	14	2878	3096	0	0	1472	2	6
311	127	976	754	21	2463	2575	0	0	1285	0	0
280	80	937	912	43	2533	2649	0	0	1685	0	0
237	99	796	601	11	1983	2120	0	0	1151	16	0
232	85	817	630	12	1951	1979	0	0	960	0	0
307	93	884	672	17	2248	2397	0	0	1092	4	2
331	185	1265	712	25	2774	3023	0	0			

* Ladies were not admitted by purchased Tickets until 1843.

† Tickets for admission to Sections only.

‡ Including Ladies.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE GENERAL TREASURER'S ACCOUNT from August 25 1875 (commencement of BRISTOL Meeting) to September 6, 1876 (GLASGOW) Not including Receipts on account of Glasgow Meeting

RECEIPTS

	£	s	d
To Balance brought from last Account	624	1	8
Received for Life Compositions at Bristol Meeting and since	419	0	0
" Annual Subscriptions ditto ditto	668	0	0
Associates' Tickets ditto ditto	884	0	0
" Ladies' Tickets ditto ditto	6 2	0	0
" Dividends on Stock	237	10	0
for Sale of Publications	130	8	2
Balance of Grant returned by Intestinal Secretion Committee	10	4	9
Balance of Grant returned by Geological Record Committee	73	6	3
" Balance of Grant returned by British Rainfall Committee	1	11	1
" for Transmission of Papers to Members during Bristol Meeting	6	19	6
" Interest on Deposit at London and Westminster Bank	16	11	2
	3743	12	7
	£3743	12	7

PAYMENTS

	£	s	d	£	s	d
Paid Expenses of Bristol Meeting also Sundry Printing Binding Advertising and Incidental Expenses				404	12	6
Printing Engraving &c Report of 44th Meeting Vol XLIII (Belfast)				708	2	9
Salaries (1 year)				470	0	0
Rent and Office Expenses (Albemarle Street)				104	5	[illegible]
Grants made at the Bristol Meeting viz —						
Estimation of Potash and Phosphoric Acid	13	0	0			
Physiological Action of Sound	[illegible]	0	0			
Geological Record	100	0	0			
Action of Ethyl Bromobutyrate on Ethyl Sodaceto acetate	5	0				
Intestinal Secretions	15	0	0			
Isomeric Cresols	10	0	0			
Thermal Conductivities of Rocks	0	0	0			
Zoological Record	100	0				
Elliptic Functions (printing Mathematical Tables	1 9	4	2			
Measuring Speed of Ships	10	0				
Underground Waters in New Red Sandstone	10	0	0			
Zoological Station at Naples	5	0	0			
British Rainfall	100	0	0			
Tide Calculating Machine	900	0				
Settle Cave Exploration	100	0	0			
Kent's Cavern Exploration	100	0	0			
Specific Volumes of Liquids	25	0	0			
Close Time for Protection of Indigenous Animals	5	0	0			
Testing Ohm's Law	9	1	0			
Anthropometric Committee	13	1				
Earthquakes in Scotland	1	10	0			
Effect of Propeller on Turning of Steam Ships		0	0			
1876				1092	4	2
Balance at London and Westminster Bank (current account)	£461	19	9			
Ditto ditto (deposit account)	500	0	0			
Cash in hands of General Treasurer	2	8	5			
				964	8	2
				£3743	12	7

Examined with the vouchers and found correct.

G C. FOSTER
W SPOTTISWOODE
R STRACHEY } *Auditors*

A W WILLIAMSON
September 6 1876

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE GLASGOW MEETING

SECTION A.—MATHEMATICS AND PHYSICS.

President.—Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S., F.R.S.E.

Vice-Presidents.—Professor Blackburn, M.A.; Professor Cremona; Professor Grant, M.A., LL.D., F.R.S., F.R.A.S.; Rev. Professor Haughton, M.A., F.R.S.; Professor A. S. Herschel, B.A., F.R.A.S.; Dr. J. Janssen; Rev. Dr. Lloyd, F.R.S.; Professor Clerk Maxwell, F.R.S.; Professor G. G. Stokes, Sec. R.S.; Professor P. G. Tait, F.R.S.E.; Professor Wüllner.

Secretaries.—Professor W. F. Barrett, F.R.S.E., M.R.I.A., F.C.S.; J. T. Bottomley, M.A., F.R.S.E., F.C.S.; Professor G. Forbes, B.A., F.R.S.E.; J. W. L. Glaisher, M.A., F.R.S., F.R.A.S.; Thomas Muir, M.A., F.R.S.E.

SECTION B.—CHEMISTRY AND MINERALOGY, INCLUDING THEIR APPLICATIONS TO AGRICULTURE AND THE ARTS.

President.—W. H. Perkin, F.R.S., Secretary of the Chemical Society.

Vice-Presidents.—Professor T. Andrews, M.D., F.R.S.; Professor Crum Brown, M.D., F.R.S.E.; W. Crookes, F.R.S.; Professor J. Ferguson, M.A.; Professor G. C. Foster, F.R.S.; Dr. Gilbert, F.R.S.; Professor J. H. Gladstone, F.R.S.; Professor Edmund J. Mills, D.Sc., F.C.S.; Professor A. W. Williamson, F.R.S.; James Young, F.R.S.

Secretaries.—W. Dittmar; W. Chandler Roberts, F.R.S.; John M. Thomson, F.C.S.; W. A. Tilden, D.Sc.

SECTION C.—GEOLOGY.

President.—Professor John Young, M.D.

Vice-Presidents.—His Grace the Duke of Argyll, K.T., LL.D., F.R.S.; Professor A. Geikie, LL.D., F.R.S.; Professor E. Hull, F.R.S.; J. Gwyn Jeffreys, LL.D., F.R.S.; W. Pengelly, F.R.S.; Rev. T. Wiltshire, M.A., F.G.S.

Secretaries.—Jas. Armstrong; F. W. Rudler, F.G.S.; W. Topley, F.G.S.

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Vice-Presidents.—Professor Balfour, M.D., F.R.S.; G. Bentham, F.R.S.; Professor A. Buchanan, M.D.; Professor Cleland, M.D., F.R.S.; Dr. Ferdinand Cohn; Professor Dickson, M.D., F.L.S.; Professor Grube; Professor Haeckel; Dr. Hooker, F.R.S.; J. G. M'Kendrick, F.R.S.E.; Professor Morren; Professor Newton, F.R.S.; Dr. Redfern; Dr. Allen Thomson, F.R.S.; Sir Wyville Thomson, F.R.S.; Rev. Canon Tristram, F.R.S.; Professor W. C. Williamson, F.R.S.

Secretaries.—E. R. Alston, F.Z.S.; Hyde Clarke; Dr. Knox, M.A.; Professor W. R. M'Nab, M.D.; Dr. Muirhead; Professor Morrison Watson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

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Vice-Presidents.—General Sir James E. Alexander, K.C.B., F.R.G.S.; Sir T. E. Colebrooke, Bart., M.P.; Captain Douglas Galton, C.B., F.R.S.; A. Kinnaird, M.P.; Chevalier Cristoforo Negri; Col. R. L. Playfair; Commander F. H. Verney, R.N.

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SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

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Vice-Presidents.—G. Anderson, M.P.; Principal Caird, D.D.; Charles Cameron, LL.D., M.P.; J. G. Fitch, M.A.; J. Grieve, M.P.; G. W. Hastings; J. Heywood, F.R.S.; Judge Longfield; Lord O'Hagan; The Lord Provost of Glasgow; Sir James Watson.

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OFFICERS AND COUNCIL, 1876-77

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WILLIAM SQUARE Esq
HAMILTON WHITEFORD Esq

LOCAL TREASURER FOR THE MEETING AT PLYMOUTH

[illegible] HICKS Esq

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Professor A W WILLIAMSON Ph D F R S F C S University College London W C

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The Trustees the President and President Elect the Presidents of former years the Vice Presidents and Vice Presidents Elect the General and Assistant General Secretaries for the present and former years the General Treasurers for the present and former years and the Local Treasurer and Secretaries for the ensuing Meeting

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The Rev T R Robinson D D
Sir G B Airy Astronomer Royal
General Sir E Sabine, K C B
The Earl of Harrowby
The Duke of Argyll
The Rev H Lloyd D D
Richard Owen M D D C L
Sir W G Armstrong C B LL D
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Gen Sir E Sabine K C B F R S
W Spottiswoode Esq F R S
Dr T Thomson F R S
Dr Michael Foster F R S

AUDITORS

Professor G C Foster F R S
W Spottiswoode Esq F R S
Major General Strachey F R S

Report of the Council for the Year 1875–76, *presented to the General Committee at Glasgow on Wednesday, September* 6*th*, 1876.

The Council have much regret in announcing that Sir Robert Christison, who was elected President for the Glasgow Meeting, informed the Council in the course of last winter that he felt himself unable to preside, in consequence of the state of his health. Under these circumstances the Council selected Dr. Andrews, of Belfast, for nomination for the office of President; and the first business of the General Committee of the Association will be to confirm this nomination. The Council also recommend that Mr. J. Young, F.R.S., be elected a Vice-President of the Association.

The Council have received Reports during the past year from the General Treasurer, and his Accounts for the year will be laid before the General Committee this day.

The General Committee at Bristol referred the following four Resolutions to the Council for their consideration, and they beg to report their action thereon in each case:—

> *First Resolution.*—"That the Council be requested to consider the recommendations of the Reports of the Royal Commission on Scientific Instruction and the Advancement of Science, and to take such action thereupon as may seem to them best calculated to advance the interests of Natural Science."

The Council having considered this Resolution, waited as a deputation upon the Lord President of the Council and upon the Secretary of State for the Home Department, and urged upon the Government the opinion of the Association that it is of the highest importance to the welfare of this country that the Government should without delay give systematic material aid to the development of the higher Scientific Education, in the spirit of the Fifth and Eighth Reports of the Royal Commission on Scientific Instruction and the Advancement of Science; and the Council further urged upon the Government that, in the selection of Members of the proposed University Commission, Science should be duly represented. The Government promised to give due consideration to the representations of the British Association; and they have increased the amount of the Grant to the Royal Society for aiding Scientific Investigation.

> *Second Resolution.*—"That the Council be requested to take such steps as they think suitable for renewing their representations to the Secretary of State for India, as to the importance of establishing an Observatory for Solar Physics in India, in conformity with the recommendations of the Royal Commissioners on Scientific Instruction and the Advancement of Science."

The Council having learned that steps were being taken in India in reference to this matter, deemed it advisable to defer any action for the present.

Third Resolution.—"That the Council be requested to consider and report upon the manner in which the Members of Committees and other Officers of the Association shall be selected, and whether Ladies shall be admitted to such offices, and if so, to what offices, and under what conditions."

Upon this Resolution the Council have come to the following conclusion, viz.:—

> That it does not appear to have been the practice of the British Association to elect Ladies as Officers of the Association, or to place them upon the General or Sectional Committees, and they are of opinion that no case has been made out for altering the practice hitherto in force.

Fourth Resolution.—"That the Council be requested to take into consideration the expediency of appointing Representatives to attend the International Statistical Congress to be held at Buda-Pesth in 1876."

The Council have not taken any action on this Resolution.

The Council regret to have to announce that Dr. Michael Foster, M.A., F.R.S., is unable to continue to act as one of the General Secretaries of the Association. They cannot refrain from expressing their regret at the loss of his valuable services.

The Council have agreed to recommend that Mr Philip Lutley Sclater, F.R S., be appointed one of the General Secretaries in his place. Mr. Sclater's name will be proposed to the General Committee at the Meeting for the Election of the Council and Officers on Monday next.

The Council have added to the List of the Corresponding Members of the Association the names of the following gentlemen present at the last Meeting of the Association, viz.:—

Dr. Nachtigal.
Dr. Oppenheim.
Dr. E. L. Youmans.

The Council have been informed that invitations for the Meeting to be held in 1878, or following years, will be presented from Leeds and Dublin.

The following are the names of Members of Council for the past year who, in accordance with the regulations, are not eligible for re-election this year, viz.:—

Mr. Bateman.
Professor G. C. Foster.
Mr. Lockyer.
Right Hon. Lyon Playfair.
Dr. C. W. Siemens.

The Council recommend the re-election of the other ordinary Members of Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list:—

Abel, F. A., Esq., F.R S.
*Alcock, Sir Rutherford, K C B.
Bramwell, F. J., Esq., C.E., F.R.S.
*Cayley, Professor, F.R.S.
De La Rue, Warren, Esq., D.C.L., F.R.S.
Evans, J., Esq., F.R.S.
Farr, Dr. W., F.R.S.
Flower, Professor W. H., F.R.S.
*Froude, W., Esq., F.R.S.
Gassiot, J. P., Esq., D.C.L., LL.D., F.R S.
Heywood, J., Esq., F.R.S.
*Houghton, Lord, F.R.S.
*Huggins, W., Esq., F.R.S.
Jeffreys, J. Gwyn, Esq., F.R.S.
Maskelyne, Prof. N. S., M.A., F.R.S.
Maxwell Professor J. Clerk, F.R.S.

Merrifield, C. W., Esq., F.R.S.
Newton, Professor A., F.R.S.
Ommanney, Admiral E., C.B., F.R.S.
Pengelly, W., Esq., F.R.S.
Prestwich, Professor J., F.R.S.
Rolleston, Professor G., M.A., F.R.S.
Roscoe, Professor H. E., Ph.D., F.R.S.
Russell, Dr. W. J., F.R.S.
Smith, Professor H. J. S., F.R.S.

Recommendations adopted by the General Committee at the Glasgow Meeting in September 1876.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

Involving Grants of Money.

That the Committee on Underground Temperature, consisting of Professor Everett, Professor Sir W. Thomson, Professor J. Clerk Maxwell, Mr. G. J. Symons, Professor Ramsay, Professor Geikie, Mr. J. Glaisher, Mr. Pengelly, Professor Edward Hull, Professor Ansted, Dr. Clement Le Neve Foster, Professor A. S. Herschel, Mr. G. A. Lebour, Mr. A. B. Wynne, Mr. Galloway, and Mr. Joseph Dickinson, be reappointed; that Professor Everett be the Secretary, and that the sum of £50 be placed at their disposal.

That the Committee, consisting of Professor Stokes, Dr. De La Rue, Professor Clerk Maxwell, Professor W. F. Barrett, Mr. Howard Grubb, Mr. G. Johnstone Stoney, and Professor R. S. Ball, for examining and reporting upon the reflective powers of silver, gold, and platinum, whether in mass or chemically deposited on glass, and of speculum metal, be reappointed; and that the grant of £20 which has lapsed be renewed.

That Professor Sir William Thomson, Professor Tait, Professor Grant, Dr. Siemens, and Professor Purser be appointed a Committee to undertake experiments for the Measurement of the Lunar Disturbance of Gravity; and that the sum of £50 be placed at their disposal for the purpose.

That the Committee on Thermo-Electricity, consisting of Professor Tait, Professor Tyndall, and Professor Balfour Stewart, be reappointed; and that the grant of £50 which has lapsed be renewed.

That the Committee, consisting of Professor Cayley, Professor G. G. Stokes, Professor H. J. S. Smith, Professor Sir W. Thomson, and Mr. J. W. L. Glaisher (Secretary), be reappointed; that the tables of the Elliptic Functions be completed and published; that the sum of £250 be placed at the disposal of the Committee for the purpose; and that it be referred to the Council to settle the details of publication.

That the Committee, consisting of Dr. Joule, Professor Sir W. Thomson, Professor Tait, Professor Balfour Stewart, and Professor J. Clerk Maxwell, for effecting the determination of the Mechanical Equivalent of Heat, be reappointed; and that the sum of £100 be placed at their disposal for the purpose.

That the Committee on Luminous Meteors, consisting of Mr. James Glaisher, Mr. R. P. Greg, Mr. Charles Brooke, Dr. Flight, Professor G. Forbes, and Professor A. S. Herschel, be reappointed; that Professor Herschel be the Secretary, and that the sum of £30 be placed at their disposal.

That Professor G. Forbes and Professor Sir W. Thomson be a Committee for the purpose of endeavouring to make arrangements for the taking of certain observations of Atmospheric Electricity in India; that Professor G. Forbes be the Secretary, and that the sum of £15 be placed at their disposal for the purpose

That the Committee for investigating the methods employed in the estimation of Potash and Phosphoric Acid in commercial products be reappointed; also that Mr E W Parnell and Mr Ogilvie be added to the Committee; that Mr Allen be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Dr. William Wallace, Professor Dittmar, and Mr. Thomas Wills be a Committee for the purpose of reporting on the best means for the development of Light from Coal-gas of different qualities, that Dr. Wallace be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That the Committee, consisting of Dr. F Clowes and Dr. W. A Tilden, for the purpose of examining the Action of Ethylbromo-butyrate on Ethyl Sod-aceto-acetate, be reappointed, that Dr Clowes be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That the Committee, consisting of Dr Armstrong, Professor Thorpe, and Mr. W. W Fisher, for the purpose of investigating the Isomeric Cresols and the Law of Substitution in the Phenol Series, be reappointed; that Dr. Armstrong be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Mr. W. N. Hartley, Mr J. M Thomson, and Mr. W Chandler Roberts be a Committee for the purpose of investigating the Constitution of Double Compounds of Cobalt and Nickel, that Mr. J M. Thomson be the Secretary, and that the sum of £10 be placed at their disposal for the purpose

That Dr Crum-Brown, and Messrs Dewar, Dittmar, and Dixon be a Committee for the purpose of investigating some methods that have been recently proposed for the Quantitative Estimation of Atmospheric Ozone, that Mr. E. M. Dixon be the Secretary, and that the sum of £15 be placed at their disposal for the purpose

That Mr W. N Hartley, Dr E J. Mills, and Mr W. Chandler Roberts be a Committee for the purpose of investigating the conditions under which liquid Carbonic Acid occurs in Minerals, that Mr. W. N. Hartley be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Mr. J. Evans, Sir J. Lubbock, Bart, Mr E. Vivian, Mr. W. Pengelly, Mr. G. Busk, Professor W. Boyd Dawkins, Mr. W. Ayshford Sandford, and Mr. J. E. Lee be a Committee for the purpose of continuing the exploration of Kent's Cavern, Torquay; that Mr. Pengelly be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Sir John Lubbock, Bart, Professor Prestwich, Professor Busk, Professor Hughes, Professor W. Boyd Dawkins, Rev. H. W. Crosskey, Messrs. L. C. Miall and R. H. Tiddeman be reappointed a Committee for the purpose of assisting in the exploration of the Victoria Cave, that Mr. Tiddeman be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Mr. J. Evans, Rev. T. G. Bonney, Professors A. H. Green and H. A. Nicholson, Messrs. W. Carruthers, F. Drew, R. Etheridge, Jun., G. A. Lebour, L. C. Miall, F. W. Rudler, E. B. Tawney, W. Topley, and W. Whitaker be a Committee for the purpose of carrying on the Geological

Record; that Mr. Whitaker be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Professor Hull, Mr. E. W. Binney, Mr. H Howell, Mr. M. Reade, Rev. H. W. Crosskey, Professor A. H. Green, Professor Harkness, Mr. W. Molyneux, Mr. G. H. Morton, Mr. Pengelly, Professor Prestwich, Mr. J. Plant, Mr. W. Whitaker, Captain D Galton, and Mr De Rance be a a Committee for the purpose of investigating the circulation of the underground waters in the New Red Sandstone and Permian formations of England, and the quantity and character of the water supplied to various towns and districts from those formations, that Mr. C E. De Rance be the Secretary, and that the sum of £10 be placed at their disposal for the purpose

That Professor A. S. Herschel and Mr. G. A. Lebour be a Committee for the purpose of making experiments on the Thermal Conductivities of certain rocks, that Professor Herschel be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Dr. Bryce, Mr J. Brough, Mr G Forbes, Mr D. Milne-Home, Mr. J. Thomson, Professor Sir W Thomson, and Mr. Peter Drummond be a Committee for the purpose of continuing the Observations and Records of Earthquakes in Scotland; that Dr. Bryce be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Mr. W. Topley, Mr. H. Willett, Mr R. A. C. Godwin-Austen, Mr. Davidson, Prof. Prestwich, Prof. W. Boyd Dawkins, Mr. H. Woodward, and Prof. Hull be a Committee for the purpose of promoting the Sub-Wealden Exploration; that Mr. Willett and Mr. Topley be the Secretaries, and that the sum of £100 be placed at their disposal for the purpose.

That Professor Arthur Gamgee, Professor Roscoe, and Mr. Priestley be a Committee for the purpose of investigating the Physiological Action of Ortho-, Pyro-, and Metaphosphoric Acids and of allied compounds; that Professor Gamgee be the Secretary, and that the sum of £15 be placed at their disposal for the purpose.

That Dr. Hooker, Professor Oliver, and Mr. Dyer be a Committee for the purpose of preparing a Report on the Family of the Dipterocarpeæ, that Mr. Dyer be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Mr. Stainton, Sir John Lubbock, and Mr. Sclater be a Committee for the purpose of continuing a Record of Zoological Literature, that Mr. Stainton be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Professor Huxley, Dr. Carpenter, Mr. Sclater, Mr. F. M. Balfour, Dr. M. Foster, Professor Ray Lankester, and Mr. Dew-Smith be reappointed a Committee for the purpose of arranging with Dr. Dohrn for the occupation of a Table at the Zoological Station at Naples during the ensuing year; that Mr. Dew-Smith be the Secretary, and that the sum of £75 be placed at their disposal for the purpose.

That Colonel Lane Fox, Dr. Beddoe, Mr. Franks, Mr. F. Galton, Mr. E. W. Brabrook, Sir J. Lubbock, Sir W. Elliot, Mr. C. R. Markham, Mr. E. B. Tylor, Mr. J. Evans, and Mr. F. W. Rudler be reappointed a Committee for the purpose of preparing and publishing brief forms of instruction for travellers, ethnologists, and other anthropological observers; that Colonel Lane Fox be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Colonel Lane Fox, Professor Rolleston, Mr. Park Harrison, Mr. T.

H. Price, and Mr. J. R. Mortimer be a Committee for the purpose of the Exploration of Ancient Earthworks and other Prehistoric Remains, that Colonel Lane Fox be the Secretary, and that the unexpended balance of £25 be placed at their disposal for the purpose.

That Dr. Farr, Dr. Beddoe, Mr Brabrook, Sir George Campbell, the Earl of Ducie, Mr F P. Fellows, Colonel Lane Fox, Mr F. Galton, Mr. Park Harrison, Mr. J. Heywood, Mr. P Hallett, Professor Leone Levi, Sir Rawson Rawson, and Professor Rolleston be a Committee for the purpose of continuing the collection of observations on the Systematic Examination of Heights, Weights, &c. of Human beings in the British Empire, and the publication of Photographs of the typical races of the Empire; that Colonel Lane Fox be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That the Right Hon. J. G. Hubbard, M P., Mr. Chadwick, M.P., Mr. Morley, M.P., Dr Farr, Sir George Campbell, M.P., Mr. Hallett, Professor Jevons, Mr. Newmarch, Mr. Shaen, and Mr. Macneel Caird (with power to add to their number) be continued as a Committee for the purpose of further developing the investigations into a Common Measure of Value in Direct Taxation, that Mr. Hallett be the Secretary, and that the sum of £10 be placed at their disposal for the purpose of defraying expenses incurred and to be incurred in the inquiry

That the Committee on instruments for measuring the speed of ships be reappointed, that it consist of the following Members.—Mr. W. Froude, Mr. F. J. Bramwell, Mr A E. Fletcher, Rev E L Berthon, Mr James R. Napier, Mr. C. W Merrifield, Dr C W. Siemens, Mr H. M. Brunel, Mr W. Smith, Sir William Thomson, Mr. J N Shoolbred, and Professor James Thomson; that Mr. J. N. Shoolbred be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

That Professor Sir W. Thomson, Professor Clerk Maxwell, Professor Tait, Dr. C. W. Siemens, Mr. F. J. Bramwell, Mr. W Froude, and Mr. J. T. Bottomley be a Committee for the purpose of commencing secular experiments on the Elasticity of Wires; that Mr. Bottomley be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

Applications for Reports and Researches not involving Grants of Money

That the Committee, consisting of Professor Cayley, Mr. J. W. L Glaisher, Dr. W. Pole, Mr. C. W. Merrifield, Professor Fuller, Mr. H. M. Brunel, and Professor W. K. Clifford, be reappointed to estimate the cost of constructing Mr. Babbage's Analytical Engine, and to consider the advisability of printing tables by its means; and that Professor W. K. Clifford be the Secretary.

That Dr. W. Huggins, Mr. J. N. Lockyer, Professor J. Emerson Reynolds, Mr. G. J. Stoney, Mr Spottiswoode, Dr. De La Rue, and Dr. W. M. Watts be a Committee for the purpose of preparing and printing Tables of Wave-frequency (Inverse Wave-lengths), and that Mr. G. J. Stoney be the Secretary.

That the Committee, consisting of Professor Sylvester, Professor Cayley, Professor Hirst, Professor Bartholomew Price, Professor H. J. S. Smith, Dr. Spottiswoode, Mr. R. B. Hayward, Dr. Salmon, Professor R. Townsend, Professor Fuller, Professor Kelland, Mr. J. M. Wilson, Professor Henrici, Mr. J. W. L. Glaisher, and Professor Clifford, for considering the possibility of improving the methods of instruction in elementary geometry, be reappointed.

That Mr. Spottiswoode, Professor G. G. Stokes, Professor Cayley, Professor H. J. S. Smith, Professor Sir W. Thomson, Professor Henrici, Lord Rayleigh, Mr. C. Brooke, and Mr. J. W. L. Glaisher be appointed a Committee to report upon Mathematical Notation and Printing.

That the Committee on the Magnetization of Iron, Nickel, and Cobalt, consisting of Professor Balfour Stewart, Professor Clerk Maxwell, Mr. H. A. Rowland, and Professor W. F. Barrett, be reappointed.

That Professor Prestwich, Professor Harkness, Professor Hughes, Professor W. Boyd Dawkins, Rev H. W. Crosskey, Messrs. L. C. Miall, G. H. Morton, D. Mackintosh, R. H. Tiddeman, J. E. Lee, T. Plant, W. Pengelly, and Dr. Deane be a Committee for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation; that the Rev. H. W. Crosskey be the Secretary.

That the Rev. H F. Barnes, Mr. C. Spence Bate, Mr. H. E. Dresser, Dr. Gunther, Mr. J. E Harting, Dr J. Gwyn Jeffreys, Professor Newton, and Rev. Canon Tristram be a Committee for the purpose of inquiring into the possibility of establishing a "close time" for the protection of indigenous animals.

That Mr Spence Bate be requested to continue his Report "On the present state of our knowledge of the Crustacea."

That Mr. R. Bruce Bell, Mr. J. Wolfe Barry, Mr James Brownlee, Mr. Henry Brunel, Mr. St. John V Day, Mr. Edward Easton, Mr. William Froude, Sir John Hawkshaw, Professor A. B. W. Kennedy, Dr W. Pole, Mr. Hazelton Robson, Mr. David Rowan, and Mr. William Smith be a Committee for the purpose of reporting on the different kinds of Safety-valves used or designed for marine and other engines

That the Committee for the purpose of making experiments and of reporting on the effect of the Propeller on the turning of Steam-vessels be reappointed (with power to communicate with the Government), consisting of Mr. James R. Napier, Sir William Thomson, Mr. William Froude, and Professor Osborne Reynolds; that Mr J. T. Bottomley be added to the Committee, and that Professor Osborne Reynolds be the Secretary.

That the Committee, consisting of Professor Sir William Thomson, Major-General Strachey, Captain Douglas Galton, Mr. G. F. Deacon, Mr. Rogers Field, Mr. E. Roberts, and Mr. James N. Shoolbred, for the purpose of considering the Datum-level of the Ordnance Survey of Great Britain, with a view to its establishment on a surer foundation than hitherto, with power to communicate with the Government if necessary, be reappointed, that Mr. James N. Shoolbred be the Secretary.

That the Committee, consisting of Mr. W. H. Barlow, Mr. H. Bessemer, Mr. F. J. Bramwell, Captain Douglas Galton, Sir John Hawkshaw, Dr. C. W. Siemens, Professor Abel, and Mr. E. H. Carbutt, for the purpose of considering the use of steel for structural purposes, be reappointed; that Mr. E. H. Carbutt be the Secretary.

That Dr. A. W. Williamson, Professor Sir W Thomson, Mr. Vincent Day, Dr. Siemens, Mr. Merrifield, Mr. Nelson Hancock, Professor Abel, Mr. R. Napier, Captain Galton, Mr. Newmarch, Mr. Carbutt, and Mr. Macrory be a Committee for the purpose of watching and reporting to the Council on Patent Legislation; that Mr. Bramwell be the Secretary.

Resolution referred to the Council for consideration and action if it seem desirable.

That the Council be requested to consider, and to take steps if they think it desirable, to urge upon H.M. Government the advisability of forming a Museum of Scientific Instruments and Chemical Products, as suggested in the Memorial presented in June last to the Lord President of H.M. Council.

That the arrangement of the Journal of Sectional Proceedings be altered, and that the list of the papers to be read on the day of issue be placed before the list of papers read on the previous day.

That in future the Presidents-elect of the various Sections be invited to confer with the General Secretary, preparatory to the issuing of the first number of the Journal, to arrange the order in which the Sectional Addresses should be delivered, so as to afford opportunity to the Members of the Association to attend the several Addresses in those subjects in which they may be interested, and that the order in which the Addresses are to be read be announced in the first number of the Journal.

Communications ordered to be printed in extenso *in the Annual Report of the Association.*

That Professor James Thomson's paper, "Improved Investigations on the Flow of Water through Orifices, with objections to the Modes of Treatment commonly adopted," be printed *in extenso* in the Reports of the Association.

That Mr. W. J. Jansson's paper, "Nitrous Oxide in the Gaseous and Liquid States," be printed *in extenso* in the Reports of the Association.

That the paper by Mr G. Chrystal and Mr. S. A. Saunder, "On a Comparison of the B.A. Standards of Electrical Resistance," be printed *in extenso* among the Reports.

That the paper by Professor Osborne Reynolds, "On the Investigation of the Steering-qualities of Ships," be printed *in extenso* in the Reports of the Association together with the necessary Plates.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Bristol Meeting in September 1876. *The names of the Members who would be entitled to call on the General Treasurer for the respective Grants are prefixed.*

Mathematics and Physics.

*Everett, Professor.—Underground Temperature	£50	0	0
*Stokes, Professor.—Reflective Power of Silver and other Substances (renewed)	20	0	0
Thomson, Sir William.—Measurement of the Lunar Disturbance of Gravity	50	0	0
*Tait, Professor —Thermo-Electricity (renewed)	50	0	0
*Cayley, Professor.—Publication of Tables of Elliptic Functions	250	0	0
*Joule, Dr.—Determination of the Mechanical Equivalent of Heat	100	0	0
*Glaisher, Mr. J.—Luminous Meteors	30	0	0
Forbes, Prof. G.—Observation of Atmospheric Electricity in India	15	0	0

Chemistry.

*Allen, Mr.—Estimation of Potash and Phosphoric Acid	20	0	0
Wallace, Dr. W —Light from Coal Gas	20	0	0
*Clowes, Dr. F.—Action of Ethyl Bromo-butyrate on Ethyl Sodaceto-acetate (renewed)	10	0	0
*Armstrong, Dr.—Isomeric Cresols and the Law of Substitution in the Phenol Series (renewed)	10	0	0
Hartley, Mr. W. N.—Double Compounds of Cobalt and Nickel	10	0	0
Brown, Prof. Crum.—Quantitative Estimation of Atmospheric Ozone	15	0	0
Hartley, W. N.—Liquid Carbonic Acid in Minerals	20	0	0

Geology.

*Evans, Mr. J.—Kent's Cavern Exploration	100	0	0
*Lubbock, Sir J., Bart.—Exploration of Victoria Cave, Settle	100	0	0
*Evans, Mr. J.—Record of the Progress of Geology	100	0	0
*Hull, Professor.—Underground Waters in the New Red Sandstone	10	0	0
*Herschel, Professor.—Thermal Conductivities of Rocks	10	0	0
*Bryce, Dr.—Earthquakes in Scotland	10	0	0
Topley, Mr.—Sub-Wealden Epxloration	100	0	0
Carried forward	£1100	0	0

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* Reappointed.

Biology.

	£	s.	d.
Brought forward	£1100	0	0
Gamgee, Prof.—Physiological Action of Ortho-, Pyro-, and Meta-phosphoric Acids	15	0	0
Hooker, Dr.—Report on the Family of the Dipterocarpeæ	20	0	0
*Stainton, Mr.—Record of Zoological Literature	100	0	0
*Huxley, Professor.—Table at the Zoological Station at Naples	75	0	0
*Fox, Col Lane.—Exploration of Ancient Earthworks (renewed)	25	0	0
*Fox, Col. Lane.—Instructions for the use of Travellers	25	0	0

Statistics and Economic Science.

*Farr, Dr.—Anthropometric Committee (partly renewed)	100	0	0
*Hubbard, Right Hon. J. G.—Common Measure of Value in Direct Taxation	10	0	0

Mechanics.

*Froude, Mr. W.—Instruments for Measuring the Speed of Ships (partly renewed)	50	0	0
Thomson, Sir William.—Secular Experiments on the Elasticity of Wires	100	0	0
Total	£1620	0	0

* Reappointed.

The Annual Meeting in 1877.

The Meeting at Plymouth will commence on Wednesday, August 15, 1877.

Place of Meeting in 1878.

The Annual Meeting of the Association in 1878 will be held at Dublin.

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s	d
1834			
Tide Discussions	20	0	0
1835			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations &c	50	0	0
Experiments on long continued Heat	17	1	0
Rain Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0
1837			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	89	5	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6
1838			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	6
	£956	12	2
1839			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam vessels Engines	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R A S Catalogue	6	16	6
Animal Secretions .	10	10	0
Steam engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population .	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents ..	3	0	0
Mud in Rivers .	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste) .	185	0	0

	£	s	d
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	6
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	0	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842

	£	s	d
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843

	£	s	d
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Cooperation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844

	£	s	d
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	8
Instruments for Kew Observatory	56	7	3

	£	s	d.
Influence of Light on Plants......	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata ...	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells . .	20	0	0
Radiata and Mollusca of the Ægean and Red Seas . .1842	100	0	0
Geographical Distributions of Marine Zoology ...... .1842	10	0	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu .	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument ... .1842	10	3	6
	£981	12	8

1845.

	£	s	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Cooperation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth . ..	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph... ..	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds ... .1844	7	0	0
Marine Zoology of Cornwall ...	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£830	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells.	10	0	0
Vitality of Seeds .... .1844	2	15	10
Vitality of Seeds ... . .. .1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain ...	10	0	0
Exotic Anoplura .. . 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves ....,	3	3	3
Captive Balloons 1844	8	19	3
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals ..	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants...	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on account of Anemometrical Observations	13	9	0
	£160	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves ...	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

	£	s	d
1851			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7
1853			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4
1856			
Maintaining the Establishment at Kew Observatory:— 1854, £ 75 0 0; 1855, £500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life Boats	5	0	0
	£507	15	4
1858			
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2
1859			
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1
1860			
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0

	£	s.	d.
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£1241	7	0

1861

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860 ......£50 0 0 1861 . £22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	1
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
—— Construction and distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0

	£	s	d
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	0
Luminous Meteors	40	0	0
	£1591	7	10

1866

	£	s	d
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf Bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	20	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867

	£	s	d
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations .	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf Beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyle and Methyle series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868

	£	s	d
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl series	25	0	0
Mercury and Bile	25	0	0
Organic remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869

	£	s	d
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0

	£	s	d
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870

	£	s	d
Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron &c	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871

	£	s	d
Maintaining the Establishment of Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Corals Sections for Photographing	20	0	0
Bagshot Leaf Beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	10	0	0
	£1472	2	6

1872

	£	s	d
Maintaining the Establishment of Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-Embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-Lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873

	£	s	d
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-Lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874

	£	s	d
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions &c	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorological Research	100	0	0
Magnetization of Iron	20	0	0
Marine Organisms	30	0	0
Fossils North west of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone Corals	25	0	0
Erratic Blocks	10	0	0
Dredging Durham and Yorkshire Coasts	28	5	0
High temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal Measures	7	15	0
	£1151	16	0

1875

	£	s	d
Elliptic Functions	100	0	0
Magnetization of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0
Specific Volume of Liquids	25	0	0
Estimation of Potash and Phosphoric Acid	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations	100	0	0
Kent's Cavern Exploration	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record	100	0	0
Instructions for Travellers	20	0	0
Intestinal Secretion	20	0	0
Palestine Exploration .	100	0	0
	£960	0	0

1876

	£	s	d
Printing Mathematical Tables	159	4	2
British Rainfall	100	0	0
Ohm's Law	9	15	0
Tide Calculating Machine	200	0	0
Specific Volume of Liquids	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto acetate	5	0	0
Estimation of Potash and Phosphoric Acid	13	0	0
Exploration of Victoria Cave Settle	100	0	0
Geological Record	100	0	0
Kent's Cavern Exploration	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland	1	10	0
Zoological Record	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Zoological Station	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles	13	15	0
Measuring Speed of Ships	10	0	0
Effect of Propeller on turning of Steam Vessels	5	0	0
	£1092	4	2

General Meetings.

On Wednesday, September 6, at 8 P.M., in the Garden Palace, Botanic Gardens, Sir John Hawkshaw, C.E., F.R.S., F.G.S., President, resigned the office of President to Professor Thomas Andrews, M.D., LL.D., F.R.S., who took the Chair, and delivered an Address, for which see page lxviii.

On Thursday, September 7, at 8 P.M., two Soirées took place, one in the Royal Exchange, the other in the Corporation Galleries.

On Friday, September 8, at 8.30 P.M., in the Garden Palace, Botanic Gardens, Professor Tait, F.R.S.E., delivered a Discourse on "Force."

On Saturday, September 9, at 8 P.M., in the City Hall, Commander Cameron, R.N., C.B., delivered a Lecture, on "A Journey through Africa," to the Working Classes of Glasgow.

On Monday, September 11, at 8.30 P.M., in the Garden Palace, Botanic Gardens, Professor Wyville Thomson, LL.D., F.R.S., delivered a Discourse on "The 'Challenger' Expedition."

On Tuesday, September 12, at 8 P.M., a Soirée took place in the Garden Palace, Botanic Gardens.

On Wednesday, September 13, at 2.30 P.M., the concluding General Meeting took place, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The Meeting was then adjourned to Plymouth*.

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* The Meeting is appointed to take place on Wednesday, August 15, 1877.

ADDRESS

OF

THOMAS ANDREWS, M.D., LL.D.,

F.R.S., HON. F.R.S.E., ETC.

PRESIDENT

Six and thirty years have passed over since the British Association for the Advancement of Science held its tenth meeting in this ancient city, and twenty-one years have elapsed since it last assembled here. The representatives of two great Scottish families presided on these occasions; and those who had the advantage of hearing the address of the Duke of Argyll in 1855 will recall the gratification they enjoyed while listening to the thoughtful sentiments which reflected a mind of rare cultivation and varied acquirements. On the present occasion I have undertaken, not without anxiety, the duty of filling an office at first accepted by one whom Scotland and the Association would alike have rejoiced to see in this Chair, not only as a tribute to his own scientific services, but also as recognizing in him the worthy representative of that long line of able men who have upheld the preeminent position attained by the Scottish schools of medicine in the middle of the last century, when the mantle of Boerhaave fell upon Monro and Cullen.

The task of addressing this Association, always a difficult one, is not rendered easier when the meeting is held in a place which presents the rare combination of being at once an ancient seat of learning and a great centre of modern industry. Time will not permit me to refer to the distinguished men who in early days have left here their mark behind them; and I regret it the more, as there is a growing tendency to exaggerate the value of later discoveries, and to underrate the achievements of those who have lived before us. Confining our attention to a period reaching back to little more than a century, it appears that during that time three new sciences arose, at least as far as any science can be said to have a distinct origin, in this city of

Glasgow—Experimental Chemistry, Political Economy, and Mechanical Engineering. It is now conceded that Black laid the foundation of modern chemistry; and no one has ever disputed the claims of Adam Smith and of Watt to having not only founded, but largely built up, the two great branches of knowledge with which their names will always be inseparably connected. It was here that Dr. Thomas Thomson established the first school of Practical Chemistry in Great Britain, and that Sir W. Hooker gave to the chair of Botany a European celebrity; it was here that Graham discovered the law of gaseous diffusion and the properties of polybasic acids; it was here that Stenhouse and Anderson, Rankine and J. Thomson made some of their finest discoveries; and it was here that Sir William Thomson conducted his physico-mathematical investigations, and invented those exquisite instruments, valuable alike for ocean telegraphy and for scientific use, which are among the finest trophies of recent science. Nor must the names of Tennant, Mackintosh, Neilson, Walter Crum, Young, and Napier be omitted, who, with many others in this place, have made large and valuable additions to practical science.

The safe return of the 'Challenger,' after an absence of three and a half years, is a subject of general congratulation. Our knowledge of the varied forms of animal life, and of the remains of animal life, which occur, it is now known, over large tracts of the bed of the ocean, is chiefly derived from the observations made in the 'Challenger' and in the previous deep-sea expeditions which were organized by Sir Wyville Thomson and Dr. Carpenter. The physical observations, and especially those on the temperature of the ocean, which were systematically conducted throughout the whole voyage of the 'Challenger,' have already supplied valuable data for the resolution of the great question of ocean-currents. Upon this question, which has been discussed with singular ability, but under different aspects, by Dr. Carpenter and Mr. Croll, I cannot attempt here to enter; nor will I venture to forestall, by any crude analysis of my own, the narrative which Sir W. Thomson has kindly undertaken to give of his own achievements and of those of his staff during their long scientific cruise.

Another expedition, which has more than fulfilled the expectations of the public, is Lieutenant Cameron's remarkable journey across the continent of Africa. It is by such enterprises, happily conceived and ably executed, that we may hope at no distant day to see the Arab slave-dealer replaced by the legitimate trader, and the depressed populations of Africa gradually brought within the pale of civilized life.

From the North Polar Expedition no intelligence has been received; nor can we expect for some time to hear whether it has succeeded in the crowning object of Arctic enterprise. In the opinion of many, the results, scientific or other, to be gained by a full survey of the Arctic regions can never be of such value as to justify the risk and cost which must be incurred. But it is not by cold calculations of this kind that great discoveries are made or great enterprises achieved. There is an inward and irrepressible impulse—in individuals called a spirit of adventure, in nations a spirit of enterprise—which impels mankind forward to explore every part of the world we inhabit, however inhospitable or difficult of access, and if the country claiming the foremost place among maritime nations shrink from an undertaking because it is perilous, other countries will not be slow to seize the post of honour. If it be possible for man to reach the poles of the earth, whether north or south, the feat must sooner or later be accomplished, and the country of the successful adventurers will be thereby raised in the scale of nations.

The passage of Venus over the sun's disk is an event which cannot be passed over without notice, although many of the circumstances connected with it have already become historical. It was to observe this rare astronomical phenomenon, on the occasion of its former occurrence in 1769, that Captain Cook's memorable voyage to the Pacific was undertaken, in the course of which he explored the coast of New South Wales, and added that great country to the possessions of the British Crown

As the transit of Venus gives the most exact method of calculating the distance of the earth from the sun, extensive preparations were made on the last occasion for observing it at selected stations—from Siberia in northern, to Kerguelen's Land in southern latitudes. The great maritime powers vied with each other to turn the opportunity to the best account, and Lord Lindsay had the spirit to equip, at his own expense, the most complete expedition which left the shores of this country. Some of the most valuable stations in southern latitudes were desert islands, rarely free from mist or tempest, and without harbours or shelter of any kind. The landing of the instruments was in many cases attended with great difficulty and even personal risk. Photography lent its aid to record automatically the progress of the transit, and M Janssen contrived a revolving plate, by means of which from fifty to sixty images of the edge of the sun could be taken at short intervals during the critical periods of the phenomenon.

The observations of M Janssen at Nagasaki, in Japan, were of special interest Looking through a violet-blue glass he saw Venus, two or three minutes before the transit began, having the appearance of a pale round spot near the edge of the sun. Immediately after contact the segment of the planet's disk, as seen on the face of the sun, formed with what remained of this spot a complete circle. The pale spot when first seen was, in short, a partial eclipse of the solar corona, which was thus proved beyond dispute to be a luminous atmosphere surrounding the sun. Indications were at the same time obtained of the existence of an atmosphere around Venus.

The mean distance of the earth from the sun was long supposed to have been fixed within a very small limit of error at about 95,000,000 miles. The accuracy of this number had already been called in question on theoretical grounds by Hansen and Leverrier, when Foucault, in 1862, decided the question by an experiment of extraordinary delicacy. Taking advantage of the revolving-mirror, with which Wheatstone had some time before enriched the physical sciences, Foucault succeeded in measuring the absolute velocity of light in space by experiments on a beam of light, reflected backwards and forwards, within a tube little more than thirteen feet in length. Combining the result thus obtained with what is called by astronomers the constant of aberration, Foucault calculated the distance of the earth from the sun, and found it to be one thirtieth part, or about 3,000,000 miles, less than the commonly received number. This conclusion has lately been confirmed by M Cornu, from a new determination he has made of the velocity of light according to the method of Fizeau, and in complete accordance with these results are the investigations of Leverrier, founded on a comparison with theory of the observed motions of the sun and of the planets Venus and Mars It remains to be seen whether the recent observations of the transit of Venus, when reduced, will be sufficiently concordant to fix with even greater precision the true distance of the earth from the sun.

In this brief reference to one of the finest results of modern science, I have mentioned a great name whose loss England has recently had to deplore, and in connexion with it the name of an illustrious physicist whose premature death deprived France, a few years ago, of one of her brightest ornaments--Wheatstone and Foucault, ever to be remembered for their marvellous power of eliciting, like Galileo and Newton, from familiar phenomena the highest truths of nature!

The discovery of Huggins that some of the fixed stars are moving towards and others receding from our system, has been fully confirmed by a careful series of observations lately made by Mr. Christie in the Observatory of Greenwich. Mr Huggins has not been able to discover any indications of a proper motion in the nebulæ, but this may arise from the motion of translation being less than the method would discover. Few achievements in the history of science are more wonderful than the measurement of the proper motions of the fixed stars, from observing the relative position of two delicate lines of light in the field of the telescope.

The observation of the American astronomer Young, that bright lines, corresponding to the ordinary lines of Fraunhofer reversed, may be seen in the lower strata of the solar atmosphere for a few moments during a total eclipse, has been confirmed by Mr Stone, on the occasion of the total eclipse of the sun which occurred some time ago in South Africa. In the outer corona, or higher regions of the sun's atmosphere, a single green line only was seen, the same which had been already described by Young

I can here refer only in general terms to the observations of Roscoe and Schuster on the absorption-bands of potassium and sodium, and to the investigations of Lockyer on the absorptive powers of metallic and metalloidal vapours at different temperatures. From the vapour of calcium the latter has obtained two wholly distinct spectra, one belonging to a low, and the other to a high temperature. Mr Lockyer is also engaged on a new and greatly extended map of the solar spectrum.

Spectrum analysis has lately led to the discovery of a new metal—gallium —the fifth whose presence has been first indicated by that powerful agent. This discovery is due to M Lecoq de Boisbaudran, already favourably known by a work on the application of the spectroscope to chemical analysis.

Our knowledge of aerolites has of late years been greatly increased, and I cannot occupy a few moments of your time more usefully than by briefly referring to the subject So recently as 1860 the most remarkable meteoric fall on record, not even excepting that of L'Aigle, occurred near the village of New Concord in Ohio On a day when no thunder-clouds were visible, loud sounds were heard resembling claps of thunder, followed by a large fall of meteoric stones, some of which were distinctly seen to strike the earth One stone, above 50 pounds in weight, buried itself to the depth of two feet in the ground, and when dug out was found to be still warm. In 1872 another remarkable meteorite, at first seen as a brilliant star with a luminous train, burst near Orvinio in Italy, and six fragments of it were afterwards collected.

Isolated masses of metallic iron, or rather of an alloy of iron and nickel, similar in composition and properties to the iron usually diffused in meteoric stones, have been found here and there on the surface of the earth, some of large size, as one described by Pallas, which weighed about two thirds of a ton Of the meteoric origin of these masses of iron there is little room for doubt, although no record exists of their fall. Sir Edward Sabine, whose life has been devoted with rare fidelity to the pursuit of science, and to whose untiring efforts this Association largely owes the position it now occupies, was the pioneer of the newer discoveries in meteoric science Eight and fifty years ago he visited with Captain Ross the northern shores of Baffin's Bay, and made the interesting discovery that the knife-blades used by the Esquimaux in the vicinity of the Arctic highlands were formed of meteoric iron. This observation was afterwards fully confirmed; and scattered blocks of meteoric iron have been found from time to time around Baffin's Bay. But it was not till 1870 that the meteoric treasures of Baffin's Bay were truly discovered. In that year Nordenskiold found, at a part of the shore difficult of approach even in moderate weather, enormous blocks of meteoric iron, the largest weighing nearly twenty tons, imbedded in a ridge of basaltic rock. The interest of this observation is greatly enhanced by the circumstance that these masses of meteoric iron, like the basalt with which they are associated, do not belong to the present geological epoch, but must have fallen long before the actual arrangement of land and sea existed,—during, in short, the middle Tertiary, or Miocene period of

Lyell. The meteoric origin of these iron masses from Ovifak has been called in question by Lawrence Smith, and it is no doubt possible that they may have been raised by upheaval from the interior of the earth I have indeed myself shown by a magneto-chemical process that metallic iron, in particles so fine that they have never yet been actually seen, is everywhere diffused through the Miocene basalt of Slieve Mish in Antrim, and may likewise be discovered by careful search in almost all igneous and in many metamorphic rocks These observations have since been verified by Reuss in the case of the Bohemian basalts. But, as regards the native iron of Ovifak, the weight of evidence appears to be in favour of the conclusion, at which M. Daubrée, after a careful discussion of the subject, has arrived—that it is really of meteoric origin. This Ovifak iron is also remarkable from containing a considerable amount of carbon, partly combined with the iron, partly diffused through the metallic mass in a form resembling coke. In connexion with this subject, I must refer to the able and exhaustive memoirs of Maskelyne on the Busti and other aerolites, to the discovery of vanadium by R. Apjohn in a meteoric iron, to the interesting observations of Sorby, and to the researches of Daubrée, Wohler, Lawrence Smith, Tschermak, and others.

The important services which the Kew Observatory has rendered to meteorology and to solar physics have been fully recognized, and Mr Gassiot has had the gratification of witnessing the final success of his long and noble efforts to place this observatory upon a permanent footing. A physical observatory for somewhat similar objects, but on a larger scale, is in course of erection, under the guidance of M. Janssen, at Fontenay in France, and others are springing up or already exist in Germany and Italy It is earnestly to be hoped that this country will not lag behind in providing physical observatories on a scale worthy of the nation and commensurate with the importance of the object On this question I cannot do better than refer to the high authority of Dr Balfour Stewart, and to the views he expressed in his able address last year to the Physical Section.

Weather telegraphy, or the reporting by telegraph the state of the weather at selected stations to a central office, so that notice of the probable approach of storms may be given to the seaports, has become in this country an organized system; and considering the little progress meteorology has made as a science, the results may be considered to be on the whole satisfactory. Of the warnings issued of late years, four out of five were justified by the occurrence of gales or strong winds. Few storms occurred for which no warnings had been given; but unfortunately among these were some of the heaviest gales of the period. The stations from which daily reports are sent to the meteorological office in London embrace the whole coast of Western Europe, including the Shetland Isles. It appears that atmospheric disturbances seldom cross the Atlantic without being greatly altered in character, and that the origin of most of our storms lies eastward of the longitude of Newfoundland.

As regards the velocity of the wind, the cup-anemometer of Dr. Robinson has fully realized the expectations of its discoverer, and the venerable astronomer of Armagh has been engaged during the past summer, with all the ardour of youth, in a course of laborious experiments to determine the constants of his instrument. From seven years' observations at the Observatory of Armagh, he has found that the mean velocity of the wind is greatest in the S.S.W octant and least in the opposite one, and that the amount of wind attains a maximum in January, after which it steadily decreases, with one slight exception, till July, augmenting again till the end of the year

Passing to the subject of electricity, it is with pleasure that I have to announce the failure of a recent attempt to deprive Oerstedt of his great discovery. It is gratifying thus to find high reputations vindicated, and names which all men love to honour transmitted with undiminished lustre to posterity. At a former meeting of this Association, remarkable for an unusual attendance of distinguished foreigners, the central figure was Oerstedt. On that occasion Sir John Herschel in glowing language compared Oerstedt's discovery to the blessed dew of heaven which only the master-mind could draw down, but which it was for others to turn to account and use for the fertilization of the earth. To Franklin, Volta, Coulomb, Oerstedt, Ampère, Faraday, Seebeck, and Ohm are due the fundamental discoveries of modern electricity—a science whose applications in Davy's hands led to grander results than alchemist ever dreamed of, and in the hands of others (among whom Wheatstone, Morse, and Thomson occupy the foremost place) to the marvels of the electric telegraph. When we proceed from the actual phenomena of electricity to the molecular conditions upon which those phenomena depend, we are confronted with questions as recondite as any with which the physicist has had to deal, but towards the solution of which the researches of Faraday have contributed the most precious materials. The theory of electrical and magnetic action occupied formerly the powerful minds of Poisson, Green, and Gauss; and among the living it will surely not be invidious to cite the names of Weber, Helmholtz, Thomson, and Clerk Maxwell. The work of the latter on electricity is an original essay worthy in every way of the great reputation and of the clear and far-seeing intellect of its author.

Among recent investigations I must refer to Professor Tait's discovery of consecutive neutral points in certain thermo-electric junctions, for which he was lately awarded the Keith prize. This discovery has been the result of an elaborate investigation of the properties of thermo-electric currents, and is specially interesting in reference to the theory of dynamical electricity. Nor can I omit to mention the very interesting and original experiments of

Dr. Kerr on the dielectric state, from which it appears that when electricity of high tension is passed through dielectrics, a change of molecular arrangement occurs, slowly in the case of solids, quickly in the case of liquids, and that the lines of electric force are in some cases lines of compression, in other cases lines of extension.

Of the many discoveries in physical science due to Sir William Grove, the earliest and not the least important is the battery which bears his name, and is to this day the most powerful of all voltaic arrangements; but with a Grove's battery of 50 or even 100 cells in vigorous action, the spark will not pass through an appreciable distance of cold air. By using a very large number of cells, carefully insulated and charged with water, Mr. Gassiot succeeded in obtaining a short spark through air; and lately De La Rue and Muller have constructed a large chloride-of-silver battery giving freely sparks through cold air, which, when a column of pure water is interposed in the circuit, accurately resemble those of the common electrical machine. The length of the spark increasing nearly as the square of the number of cells, it has been calculated that with 100,000 elements of this battery the discharge should take place through a distance of no less than eight feet in air.

In the solar beam we have an agent of surpassing power, the investigation of whose properties by Newton forms an epoch in the history of experimental science scarcely less important than the discovery of the law of gravitation in the history of physical astronomy. Three actions characterize the solar beam, or, indeed, more or less that of any luminous body—the heating, the physiological, and the chemical. In the ordinary solar beam we can modify the relative amount of these actions by passing it through different media, and we can thus have luminous rays with little heating or little chemical action. In the case of the moon's rays it required the highest skill on the part of Lord Rosse, even with all the resources of the observatory of Parsonstown, to investigate their heating properties, and to show that the surface of our satellite facing the earth passes, during every lunation, through a greater range of temperature than the difference between the freezing- and boiling-points of water.

But if, instead of taking an ordinary ray of light, we analyze it as Newton did by the prism, and isolate a very fine line of the spectrum (theoretically a line of infinite tenuity), that is to say, if we take a ray of definite refrangibility, it will be found impossible by screens or otherwise to alter its properties. It was his clear perception of the truth of this principle that led Stokes to his great discovery of the cause of epipolic dispersion, in which he showed that many bodies had the power of absorbing dark rays of high refrangibility and of emitting them as luminous rays of lower refrangibility—of absorbing, in short, darkness and of emitting it as light. It is not, indeed, an easy matter in all cases to say whether a given effect is due to the action of heat or light; and the question which of these forces is the efficient agent in causing the motion of the tiny disks in Crookes's radiometer has given rise to a good deal of discussion. The answer to this question involves the same principles as those by which the image traced on the daguerreotype plate, or the decomposition of carbonic acid by the leaves of plants, is referred to the action of light and not of heat, and applying these principles to the experiments made with the radiometer, the weight of evidence appears to be in favour of the view that the repulsion of the blackened surfaces of the disks is due to a thermal reaction occurring in a highly rarefied medium. I have myself had the pleasure of witnessing many of Mr. Crookes's experiments, and I cannot sufficiently express my admiration of the care and skill with which he has pursued this investigation The remarkable repulsions he has observed in the most perfect vacua hitherto attained are interesting, not only as having led to the construction of a beautiful instrument, but as being likely, when the subject is fully investigated, to give valuable data for the theory of molecular actions.

A singular property of light, discovered a short time ago by Mr Willoughby Smith, is its power of diminishing the electrical resistance of the element selenium. This property has been ascertained to belong chiefly to the luminous rays on the red side of the spectrum, being nearly absent in the violet or more refrangible rays and also in heat-rays of low refrangibility. The recent experiments of Prof. W. G. Adams have fully established the accuracy of the remarkable observation, first made by Lord Rosse, that the action appeared to vary inversely as the simple distance of the illuminating source.

Switzerland sent, some years ago, as its representative to this country the celebrated De la Rive, whose scientific life formed lately the subject of an eloquent *éloge* from the pen of M. Dumas. On this occasion we have to welcome, in General Menabrea, a distinguished representative both of the kingdom of Italy and of Italian science His great work on the determination of the pressures and tensions in an elastic system is of too abstruse a character to be discussed in this address, but the principle it contains may be briefly stated in the following words:—"When any elastic system places itself in equilibrium under the action of external forces, the work developed by the internal forces is a minimum." General Menabrea has, however, other and special claims upon us here, as the friend to whom Babbage entrusted the task of making known to the world the principles of his analytical machine —a gigantic conception, the effort to realize which it is known was one of the chief objects of Babbage's later life. The latest development of this conception is to be found in the mechanical integrator of Prof. J. Thomson, in which motion is transmitted, according to a new kinematic principle, from a disk or cone to a cylinder through the intervention of a loose ball, and in Sir W. Thomson's machine for the mechanical integration of differential equations of the second order. In the exquisite tidal machine of the latter we have an instrument by means of which the height of the tide at a given port can be accurately predicted for all times of the day and night.

The attraction-meter of Siemens is an instrument of great delicacy for measuring *horizontal* attractions, which it is proposed to use for recording the attractive influences of the sun and moon, upon which the tides depend. The bathometer of the same able physicist is another remarkable instrument, in which the constant force of a spring is opposed to the variable pressure of a column of mercury. By an easy observation of the bathometer on shipboard, the depth of the sea may be approximately ascertained without the use of a sounding-line

The Loan Exhibition of Apparatus at Kensington has been a complete success, and cannot fail to be useful, both in extending a knowledge of scientific subjects and in promoting scientific research throughout the country. Unique in character, but most interesting and instructive, this exhibition will, it is to be hoped, be the precursor of a permanent museum of scientific objects, which, like the present exhibition, shall be a record of old, as well as a representation of new inventions.

It is often difficult to draw a distinct line of separation between the physical and chemical sciences, and it is perhaps doubtful whether the division is not really an artificial one. The chemist cannot, indeed, make any large advance without having to deal with physical principles; and it is to Boyle, Dalton, Gay-Lussac, and Graham that we owe the discovery of the mechanical laws which govern the properties of gases and vapours. Some of these laws have of late been made the subject of searching inquiry, which has fully confirmed their accuracy, when the body under examination approaches to what has not inaptly been designated the ideal gaseous state. But when gases are examined under varied conditions of pressure and temperature, it is found that these laws are only particular cases of more general laws, and that the laws of the gaseous state, as it exists in nature, although they may be enunciated in a precise and definite form, are very different from the simple expressions which apply to the ideal condition. The new laws become in their turn inapplicable when from the gaseous state proper we pass to those intermediate conditions which, it has been shown, link with unbroken continuity the gaseous and liquid states. As we approach the liquid state, or even when we reach it, the problem becomes more complicated, but its solution even in these cases will, it may confidently be expected, yield to the powerful means of investigation we now possess.

Among the more important researches made of late in physical chemistry, I may mention those of F. Weber on the specific heat of carbon and the allied elements, of Berthelot on thermo-chemistry, of Bunsen on spectrum analysis, of Wullner on the band- and line-spectra of the gases, and of Guthrie on the cryohydrates.

Cosmical chemistry is a science of yesterday; and yet it already abounds in facts of the highest interest. Hydrogen, which, if the absolute zero of the physicist does not bar the way, we may hope yet to see in the metallic form, appears to be everywhere present in the universe. It exists in enormous quantity in the solar atmosphere, and it has been discovered in the atmospheres of the fixed stars. It is present, and is the only known element of whose presence we are certain, in those vast sheets of ignited gas of which the nebulæ proper are composed. Nitrogen is also widely diffused among the stellar bodies, and carbon has been discovered in more than one of the comets. On the other hand, a prominent line in the spectrum of the Aurora Borealis has not been identified with that of any known element; and the question may be asked:—Does a new element, in a highly rarefied state, exist in the upper regions of our atmosphere? or are we with Ångström to attribute this line to a fluorescent or phosphorescent light produced by the electrical discharge to which the aurora is due? This question awaits further observations before it can be definitely settled, as does also that of the source of the remarkable green line which is everywhere conspicuous in the solar corona.

I must here pause for a moment to pay a passing tribute to the memory of Ångström, whose great work on the solar spectrum will always remain as one of the finest monuments of the science of our period. The influence, indeed, which the labours of Ångstrom and of Kirchhoff have exerted on the most interesting portion of later physics can scarcely be exaggerated, and it may be truly said that there are few men whose loss will be longer felt or more deeply deplored than that of the illustrious astronomer of Upsala.

I cannot pursue this subject further, nor refer to the other terrestrial elements which are present in the solar and stellar atmospheres. Among the many elements that make up the ordinary aerolite, not one has been discovered which does not occur upon this earth. On the whole we arrive at the grand conclusion that this mighty universe is chiefly built up of the same materials as the globe we inhabit.

In the application of science to the useful purposes of life, chemistry and mechanics have run an honourable race. It was in the valley of the Clyde that the chief industry of this country received, within the memory of many here present, an extraordinary impulse from the application by Neilson of the hot blast to the smelting of iron. The Bessemer steel process and the regenerative furnace of Siemens are later applications of high scientific principles to the same industry. But there is ample work yet to be done. The fuel consumed in the manufacture of iron, as, indeed, in every furnace where coal is used, is greatly in excess of what theory indicates; and the clouds of smoke which darken the atmosphere of our manufacturing towns, and even of whole districts of country, are a clear indication of the waste, but only of a small portion of the waste, arising from imperfect combustion. The depressing effect of this atmosphere upon the working population can scarcely be overrated. Their pale, I had almost said etiolated, faces are a sure indication of the absence of the vivifying influence of the solar rays, so essential to the maintenance of vigorous health. The chemist can furnish a simple test of this state of the atmosphere in the absence of ozone, the active form of oxygen, from the air of our large towns. At some future day the efforts of science to isolate, by a cheap and available process, the oxygen of the air for industrial purposes may be rewarded with success The effect of such a discovery would be to reduce the consumption of fuel to a fractional part of its present amount, and although the carbonic acid would remain, the smoke and carbonic oxide would disappear. But an abundant supply of pure oxygen is not now within our reach, and in the mean time may I venture to suggest that in many localities the waste products of the furnace might be carried off to a distance from the busy human hive by a few horizontal flues of large dimensions, terminating in lofty chimneys on a hillside or distant plain? A system of this kind has long been employed at the mercurial mines of Idria, and in other smelting-works where noxious vapours are disengaged. With a little care in the arrangements, the smoke would be wholly deposited, as flue-dust or soot, in the horizontal galleries, and would be available for the use of the agriculturist.

The future historian of organic chemistry will have to record a succession of beneficent triumphs, in which the efforts of science have led to results of the highest value to the wellbeing of man. The discovery of quinine has probably saved more human life, with the exception of that of vaccination, than any discovery of any age; and he who succeeds in devising an artificial method of preparing it will be truly a benefactor of the race. Not the least valuable, as it has been one of the most successful, of the works of our Government in India, has been the planting of the cinchona-tree on the slopes of the Himalaya. As artificial methods are discovered, one by one, of preparing the proximate principles of the useful dyes, a temporary derangement of industry occurs, but in the end the waste materials of our manufactures set free large portions of the soil for the production of human food.

The ravages of insects have ever been the terror of the agriculturist, and the injury they inflict is often incalculable. An enemy of this class, carried over from America, threatened lately with ruin some of the finest vine districts in the south of France. The occasion has called forth a chemist of high renown; and in a classical memoir recently published, M. Dumas appears to have resolved the difficult problem. His method, although immediately applied to the *Phylloxera* of the vine, is a general one, and will no doubt be found serviceable in other cases. In the apterous state the *Phylloxera* attacks the roots of the plant; and the most efficacious method hitherto known of destroying it has been to inundate the vineyard. After a long and patient investigation, M. Dumas has discovered that the sulphocarbonate of potassium, in dilute solution, fulfils every condition required from an insecticide, destroying the insect without injuring the plant. The process requires time and patience; but the trials in the vineyard have fully confirmed the experiments of the laboratory.

The application of artificial cold to practical purposes is rapidly extending; and, with the improvement of the ice-machine, the influence of this agent upon our supply of animal food from distant countries will undoubtedly be immense. The ice-machine is already employed in paraffin-works and in large breweries, and the curing or salting of meat is now largely conducted in vast chambers, maintained throughout the summer at a constant temperature by a thick covering of ice

I have now completed this brief review, rendered difficult by the abundance, not by the lack of materials. Even confining our attention to the few branches of science upon which I have ventured to touch, and omitting altogether the whole range of pure chemistry, it is with regret that I find myself constrained to make only a simple reference to the important work of Cayley on the Mathematical Theory of Isomers, and to elaborate memoirs which have recently appeared in Germany on the reflection of heat- and light-rays, and on the specific heat and conducting-power of gases for heat, by Knoblauch, E. Wiedemann, Winkelmann, and Buff.

The decline of science in England formed the theme, fifty years ago, of an elaborate essay by Babbage, but the brilliant discoveries of Faraday soon after wiped off the reproach. I will not venture to say that the alarm which has lately arisen, here and elsewhere, on the same subject will prove to be equally groundless. The duration of every great outburst of human activity, whether in art, in literature, or in science, has always been short, and experimental science has made gigantic advances during the last three centuries. The evidence of any great failure is not, however, very manifest, at least in the physical sciences. The journal of Poggendorff, which has long been a faithful record of the progress of physical research throughout the world, shows no signs of flagging, and the Jubelband by which Germany celebrated the fiftieth year of Poggendorff's invaluable services was at the same time an ovation to a scientific veteran, who has perhaps done more than any man living to encourage the highest forms of research, and a proof that in Northern Europe the physical sciences continue to be ably and actively cultivated. It in chemistry the case is somewhat weaker, the explanation, at least in this country, is chiefly to be found in the demand on the part of the public for professional aid from many of our ablest chemists.

But whatever view be taken of the actual condition of scientific research, there can be no doubt that it is both the duty and the interest of the country to encourage a pursuit so ennobling in itself, and fraught with such important consequences to the wellbeing of the community. Nor is there any question in which this Association, whose special aim is the advancement of science, can take a deeper interest. The public mind has also been awakened to its importance, and is prepared to aid in carrying out any proposal which offers a reasonable prospect of advantage

In its recent phase the question of scientific research has been mixed up with contemplated changes in the great universities of England, and particularly in the University of Oxford The national interests involved on all sides are immense and a false step once taken may be irretrievable It is with diffidence that I now refer to the subject, even after having given to it the most anxious and careful consideration

As regards the higher mathematics their cultivation has hitherto been chiefly confined to the Universities of Cambridge and Dublin, and two great mathematical schools will probably be sufficient for the kingdom The case of the physical and natural sciences is different and they ought to be cultivated in the largest and widest sense at every complete university Nor, in applying this remark to the English universities, must we forget that if Cambridge was the alma mater of Newton and Cavendish, Oxford gave birth to the Royal Society The ancient renown of Oxford will surely not suffer, while her material position cannot fail to be strengthened, by the expansion of scientific studies and the encouragement of scientific research within her walls Nor ought such a proposal to be regarded as in any way hostile to the literary studies, and especially to the ancient classical studies, which have always been so carefully cherished at Oxford If, indeed, there were any such risk, few would hesitate to exclaim—let science shift elsewhere for herself, and let literature and philosophy find shelter in Oxford! But there is no ground for any such anxiety Literature and science, philosophy and art, when properly cultivated, far from opposing will mutually aid one another There will be ample room for all, and, by judicious arrangements, all may receive the attention they deserve

A University, or Studium Generale, ought to embrace in its arrangements the whole circle of studies which involve the material interests of society, as well as those which cultivate intellectual refinement The industries of the country should look to the universities for the development of the principles of applied as well as of abstract science, and in this respect no institutions have ever had so grand a possession within easy reach as have the universities of England at this conjuncture, if only they have the courage to seize it. With their historic reputation, their collegiate endowments, their commanding influence, Oxford and Cambridge should continue to be all that they now are, but they should, moreover, attract to their lecture-halls and working cabinets students in large numbers preparing for the higher industrial pursuits of the country The great physical laboratory in Cambridge, founded and equipped by the noble representative of the House of Cavendish, has in this respect a peculiar significance, and is an important step in the direction I have indicated But a small number only of those for whom this temple of science is designed are now to be found in Cambridge It remains for the

University to perform its part, and to widen its portals so that the nation at large may reap the advantage of this well-timed foundation.

If the Universities, in accordance with the spirit of their statutes, or at least of ancient usage, would demand from the candidates for some of the higher degrees proof of original powers of investigation, they would give an important stimulus to the cultivation of science. The example of many continental universities, and among others of the venerable University of Leyden, may here be mentioned. Two proof essays recently written for the degree of Doctor of Science in Leyden, one by Van der Waals, the other by Lorenz, are works of unusual merit, and another pupil of Professor Rijke is now engaged in an elaborate experimental research as a qualification for the same degree.

The endowment of a body of scientific men devoted exclusively to original research, without the duty of teaching or other occupation, has of late been strongly advocated in this country, and M. Fremy has given the weight of his high authority to a somewhat similar proposal for the encouragement of research in France. I will not attempt to discuss the subject as a national question, the more so as after having given the proposal the most careful consideration in my power, and turned it round on every side, I have failed to discover how it could be worked so as to secure the end in view.

But whatever may be said in favour of the endowment of pure research as a national question, the Universities ought surely never to be asked to give their aid to a measure which would separate the higher intellects of the country from the flower of its youth. It is only through the influence of original minds that any great or enduring impression can be produced on the hopeful student. Without original power, and the habit of exercising it, you may have an able instructor, but you cannot have a great teacher. No man can be expected to train others in habits of observation and thought he has never acquired himself. In every age of the world the great schools of learning have, as in Athens of old, gathered around great and original minds, and never more conspicuously than in the modern schools of chemistry, which reflected the genius of Liebig, Wohler, Bunsen, and Hofmann. These schools have been nurseries of original research as well as models of scientific teaching; and students attracted to them from all countries became enthusiastically devoted to science, while they learned its methods from example even more than from precept. Will any one have the courage to assert that organic chemistry, with its many applications to the uses of mankind, would have made in a few short years the marvellous strides it has done, if Science, now as in mediæval times, had pursued her work in strict seclusion,

> Semota ab nostris rebus, seiunctaque longe,
> Ipsa suis pollens opibus, nil indiga nostri?

But while the Universities ought not to apply their resources in support of a measure which would render their teaching ineffective, and would at the same time dry up the springs of intellectual growth, they ought to admit freely to university positions men of high repute from other universities, and even without academic qualifications. An honorary degree does not necessarily imply a university education, but if it have any meaning at all, it implies that he who has obtained it is at least on a level with the ordinary graduate, and should be eligible to university positions of the highest trust.

Not less important would it be for the encouragement of learning throughout the country that the English Universities, remembering that they were founded for the same objects, and derive their authority from a common source, should be prepared to recognize the ancient universities of Scotland as freely as they have always recognized the Elizabethan University of Dublin. Such a measure would invigorate the whole university system of the country more than any other I can think of It would lead to the strengthening of the literary element in the northern, and of the practical element in the southern universities, and it would bring the highest teaching of the country everywhere more fully into harmony with the requirements of the times in which we live As an indirect result, it could not fail to give a powerful impulse to literary pursuits as well as to scientific investigations Professors would be promoted from smaller positions in one university to higher positions in another, after they had given proofs of industry and ability; and stagnation, hurtful alike to professorial and professional life, would be effectually prevented. If this union were established among the old universities, and if at the same time a new university (as I myself ten years ago earnestly proposed) were founded on sound principles amidst the great populations of Lancashire and Yorkshire, the university system of the country would gradually receive a large and useful extension, and, without losing any of its present valuable characteristics, would become more intimately related than hitherto with those great industries upon which mainly depend the strength and wealth of the nation.

It may perhaps appear to many a paradoxical assertion to maintain that the industries of the country should look to the calm and serene regions of Oxford and Cambridge for help in the troublous times of which we have now a sharp and severe note of warning. But I have not spoken on light grounds, nor without due consideration If Great Britain is to retain the commanding position she has so long occupied in skilled manufacture, the easy ways which (owing partly to the high qualities of her people, partly to the advantages of her insular position and mineral wealth) have sufficed for the past, will not be found to suffice for the future. The highest training which can be brought to bear on practical science will be imperatively required; and it will be a fatal policy if that training is to be sought for in foreign lands, because it cannot be obtained at home. The country which depends unduly on the stranger for the education of its skilled men, or neglects in its highest places this primary duty, may expect to find the demand for such skill gradually to pass away, and along with it the industry for which it was wanted. I do not claim for scientific education more than it will accomplish, nor can it ever replace the after-training of the workshop or factory Rare and powerful minds have, it is true, often been independent of it, but high education always gives an enormous advantage to the country where it prevails Let no one suppose I am now referring to elementary instruction, and much less to the active work which is going on everywhere around us, in preparing for examinations of all kinds Those things are all very useful in their way, but it is not by them alone that the practical arts are to be sustained in the country It is by education in its highest sense, based on a broad scientific foundation, and leading to the application of science to practical purposes—in itself one of the noblest pursuits of the human mind—that this result is to be reached. That education of this kind can be most effectively given in a university, or in an institution like the Polytechnic School of Zurich, which differs from the scientific side of a university only in name, and to a large extent supplements the teaching of an actual university, I am firmly convinced; and for this reason, among others, I have always deemed the establishment in this country of Examining Boards with the power of granting degrees, but with none of the higher and more important functions of a university, to have been a measure of questionable utility. It is to Oxford and Cambridge, widely extended as they can readily be, that the country should chiefly look for the development of practical science, they have abundant resources for the task; and if they wish to secure and strengthen their lofty position, they can do it in no way so effectually as by showing that in a green old age they preserve the vigour and elasticity of youth.

If any are disposed to think that I have been carrying this meeting into dream-land, let them pause and listen to the result of similar efforts to those I have been advocating, undertaken by a neighbouring country when on the verge of ruin, and steadily pursued by the same country in the climax of its prosperity. "The University of Berlin," to use the words of Hofmann, "like her sister of Bonn, is a creation of our century. It was founded in the year 1810, at a period when the pressure of foreign domination weighed almost insupportably on Prussia; and it will ever remain significant of the direction of the German mind that the great men of that time should have hoped to develop, by high intellectual training, the forces necessary for the regeneration of their country." It is not for me, especially in this place, to dwell upon the great strides which Northern Germany has made of late years in some of the largest branches of industry, and particularly in those which give a free scope for the application of scientific skill. "Let us not suppose," says M. Wurtz in his recent report on the Artificial Dyes, "that the distance is so great between theory and its industrial applications. This report would have been written in vain, if it had not brought clearly into view the immense influence of pure science upon the progress of industry. If unfortunately the sacred flame of science should burn dimly or be extinguished, the practical arts would soon fall into rapid decay. The outlay which is incurred by any country for the promotion of science and of high instruction will yield a certain return; and Germany has not had long to wait for the ingathering of the fruits of her far-sighted policy. Thirty or forty years ago, industry could scarcely be said to exist there, it is now widely spread and successful." As an illustration of the truth of these remarks, I may refer to the newest of European industries, but one which in a short space of time has attained considerable magnitude. It appears (and I make the statement on the authority of M. Wurtz) that the artificial dyes produced last year in Germany exceeded in value those of all the rest of Europe, including England and France. Yet Germany has no special advantage for this manufacture except the training of her practical chemists. We are not, it is true, to attach undue importance to a single case; but the rapid growth of other and larger industries points in the same direction, and will, I trust, secure some consideration for the suggestions I have ventured to make.

The intimate relations which exist between abstract science and its applications to the uses of life have always been kept steadily in view by this Association, and the valuable Reports, which are a monument to the industry and zeal of its members, embrace every part of the domain of science. It is with the greater confidence, therefore, that I have ventured to suggest from this Chair that no partition wall should anywhere be raised up between pure and applied science. The same sentiment animates our vigorous ally, the French Association for the Advancement of Science, which rivalling, as it already does, this Association in the high scientific character of its proceedings, bids fair in a few years to call forth the same interest in science and its results, throughout the great provincial towns of France, which the British Association may justly claim to have already effected in this country. No better proof can be given of the wide base upon which the French Association rests, than the fact that it was presided over last year by an able representative of commerce and industry, and this year by one who has long held an exalted position in the world of science, and has now the rare distinction of representing in her historic Academies the literature as well as the science of France.

Whatever be the result of our efforts to advance science and industry, it requires no gift of prophecy to declare that the boundless resources which the supreme Author and Upholder of the Universe has provided for the use of man will, as time rolls on, be more and more fully applied to the improvement of the physical and, through the improvement of the physical, to the elevation of the moral condition of the human family. Unless, however, the history of the future of our race be wholly at variance with the history of the past, the progress of mankind will be marked by alternate periods of activity and repose, nor will it be the work of any one nation or of any one race To the erection of the edifice of civilized life, as it now exists, all the higher races of the world have contributed; and if the balance were accurately struck, the claims of Asia for her portion of the work would be immense, and those of Northern Africa not insignificant Steam-power has of late years produced greater changes than probably ever occurred before in so short a time. But the resources of Nature are not confined to steam, nor to the combustion of coal The steady water-wheel and the rapid turbine are more perfect machines than the stationary steam-engine; and glacier-fed rivers with natural reservoirs, if fully turned to account, would supply an unlimited and nearly constant source of power depending solely for its continuance upon solar heat But no immediate dislocation of industry is to be feared, although the turbine is already at work on the Rhine and the Rhone. In the struggle to maintain their high position in science and its applications, the countrymen of Newton and Watt will have no ground for alarm so long as they hold fast to their old traditions, and remember that the greatest nations have fallen when they relaxed in those habits of intelligent and steady industry upon which all permanent success depends.

REPORTS

ON

THE STATE OF SCIENCE.

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Twelfth Report of the Committee for Exploring Kent's Cavern, Devonshire, the Committee consisting of JOHN EVANS, *F.R.S.*, SIR JOHN LUBBOCK, *Bart.*, *F.R.S.*, EDWARD VIVIAN, *M.A.*, GEORGE BUSK, *F.R.S.*, WILLIAM BOYD DAWKINS, *F.R.S.*, WILLIAM AYSHFORD SANFORD, *F.G.S.*, JOHN EDWARD LEE, *F.G.S.*, *and* WILLIAM PENGELLY, *F.R.S.* (*Reporter*).

THE Eleventh Report, presented by the Committee to the Association during the Meeting at Bristol in 1875, and read to the Geological Section *, brought up the narrative of the exploration to the end of July of that year. From that date the work, which is still in progress, has been carried on uninterruptedly, in all respects as in previous years; and it is intended in the present Report to describe the researches made during the thirteen months ending 31st of August of the present year.

Though the Committee have still the satisfaction of stating that they retain the valuable services of George Smerdon, foreman of the work, they have to add that Nicholas Luscombe, who had been engaged a short time before the Eleventh Report was drawn up, was obliged to leave very soon afterwards on account of illness, and that there was some difficulty in supplying his place, there being a great demand for labourers at Torquay. At the beginning of September, however, they engaged a young man named William Matthews, who has given complete satisfaction, and is still at work in the Cavern.

The Superintendents have had the pleasure, as in former years, of conducting a large number of persons into the Cavern, of explaining to them on the spot the mode of working, and describing the facts which have been discovered, as well as of setting forth their bearing on Palæontology and Anthropology. The following may be mentioned as amongst the visitors since the Eleventh Report was presented:—Lord Erskine, Hon. J. C. Erskine, Sir J. E. Duntze, Sir L. Palk, Sir J. Walrond, Colonel Bridges, Colonel Buckle (Bangalore), Major Lang, Captain F. G. D. Watson, the Revds. Chancellor Benson, T. Hincks, W. R. Stevenson, and R. R. Wolfe, Dr. Boycott, Professors of them, when the Eleventh Report was presented When Mr MacEnery and his contemporaries commenced their labours in the Cavern, the existence of this chamber was probably known to but very few persons, as what appeared to be its *two* entrances must have been so nearly filled with deposits of different kinds as to reduce them to the size of mere pigeon-holes, and it is perhaps worthy of remark, by way of confirmation, that though it contained large and lofty bosses of stalagmite, such as visitors loved to enrich with their names or initials, the only inscription found in it is dated many years after the commencement of Mr MacEnery's researches

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* See Report Brit. Assoc. 1875, pp. 1–13.

The entrance to the Labyrinth is about 190 feet from the mouth of the Long Arcade, and 280 feet from the nearest external entrance to the Cavern The name of *Labyrinth* was given to it on account of the difficulty which, without a guide, visitors experienced in threading their way between the numerous masses of fallen limestone and the large bosses of stalagmite which occupied its floor In fact it was not only the most bewildering branch of the Cavern, but even persons somewhat familiar with the scene so constantly "lost their bearings as to be unable, even after emerging from it to tell whether their way out of the Cavern lay to the right hand or to the left "There was,' says Mr MacEnery "a tradition of the loss of life here by a young man who ventured to explore it without a guide It is certain that two gentlemen who lost their light and way spent a night of horror here, dreading to advance for fear of falling into the pits they remained immovable until their friends came to their relief, alarmed by their absence" *

In another passage, speaking of the Labyrinth as "The Zigzag Route," he says, "Of the dangerous intricacies of this section of the Cavern a memorable and nearly fatal illustration occurred during the American War Some officers of the fleet then stationed in Torbay had the hardihood to attempt to explore it without a guide Having lost their clue, they wandered about in the vain hope of retracing their steps, during which their torches were burnt out They then groped about in different directions and separated After a night of horror they were released by their friends, who, alarmed at their absence, recollected the projected adventure and hastened to their deliverance" †

The Labyrinth extends from the Long Arcade, in a south-easterly direction, for about 46 feet, throwing off three narrow branches at and near its inner end Of these, the central one, opening out of the south-eastern corner, and which it is proposed to call "Matthews's Passage,' after one of the workmen, leads into the Bear's Den, another, the mouth of which is immediately adjacent and opens out of the north-eastern wall, has long been famous as "The Little Oven," and has its other end on the mass of limestone known as "The Bridge" ‡, at a distance of upwards of 60 feet towards the north, whilst the third, commencing in the southernmost corner, extends for a distance of at least from 15 to 20 feet towards the south-west The Labyrinth is commonly from 17 to 18 feet wide, but expands at one point to 22 feet, and contracts at another to 15 feet, its greatest height is 18 feet, measured from the bottom of the excavation

The walls and roof, though by no means without traces of the erosive action of flowing water, are in most places extremely rugged, and suggest by their fretted aspect that even the last of the numerous blocks of limestone encumbering its floor must have fallen a long time ago

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* See Trans Devon Assoc vol iii (1869), p 238
† Ibid p 460
‡ See Report Brit. Assoc 1873, p 199

It is separated from the Long Arcade by a massive curtain of limestone, descending from the roof to the depth of 9 feet, across a space about 18 feet wide, being, so to speak, slightly looped up at each end to form two small entrances. Observers unaccustomed to caverns are not unlikely to speculate on the cause which prevents the fall of this mass, and to hasten on lest the time before the event occurs may be undesirably brief

Mr. MacEnery had conducted some diggings in the Labyrinth, and had carried them to a depth of at least three feet at one of the entrances, so that by assuming a stooping posture ingress and egress became possible. In all other parts of the chamber his work was much less deep, and, on account of the state of the floor, was necessarily discontinuous

Omitting the large blocks of limestone, the deposits were —First, or uppermost, a Floor of Granular Stalagmite, from which there arose several huge bosses also of Stalagmite, one of which was 11 feet high above the floor, whilst its base occupied a rudely circular space fully 15 feet in mean diameter

Second, a layer of Cave-earth, rarely amounting to more than a foot in depth, and sometimes to not more than a few inches, whilst it occasionally reached as much as 2 feet.

Third Though it may be doubted whether there ever was a *Floor* of the more ancient, the Crystalline, Stalagmite in the Labyrinth, the lower, and by far the greater, part of the bosses mentioned above was of that variety, and was covered with a comparatively thin envelope of the Granular kind, without any mechanical deposit between them

Fourth, the Breccia, or, so far as is known, the most ancient of the Cavern deposits, lay immediately beneath the Cave-earth, from which there was nothing to separate it, and extended to a depth exceeding that to which the excavations were carried

In looking at the facts as they presented themselves, day after day, the following appears to be not improbably the history of the deposits in this branch of the Cavern

During, as well as after, the deposition of the Breccia, with its ursine relics, stalagmite, having now a crystalline texture, was in course of precipitation, and in such a way as to form, not *sheets* or *floors*, but *bosses* of a more or less conical form, which, whilst they rested on Breccia, had their lower slopes covered with the same material, so that their bases were deeply buried in that ancient deposit After the close of the era of the Breccia, the precipitation was still carried on, but, as before, in such a way as to add to the volume of the *bosses*, and not to produce a *floor*. Then came the deposition of the Cave-earth, containing remains of Bear, Lion, Fox, Hyæna, Mammoth, Rhinoceros, Horse, Ox, and Bird—all of them, with the exception of the first three, unknown to the Breccia. Later still was the precipitation of that stalagmite which is granular instead of crystalline, and which not only added to the dimensions of the already massive bosses, but flowed out in sheets and covered the Cave-earth. Whilst all these successive operations were in progress, blocks of limestone from time to time fell from the roof—some of them being buried in the Breccia at depths the excavators have not reached, some lying loose on the Floor of Granular Stalagmite, and others occupying all intermediate zones and representing all the intervening periods.

In order to achieve the thorough exploration of the Labyrinth, it was necessary to break up all the bosses of stalagmite with the exception of the largest of them, of which a portion has been left intact, it being believed that it shows strikingly the utter inadequacy of the data derived from a *boss* to solve the problem of the amount of time represented by a *floor*, and *vice versâ*.

Before directing the workmen, however, to remove any of these stalagmitic accumulations, the Superintendents carefully examined them for inscriptions. Nevertheless, one inscription was overlooked—that already referred to as the only specimen of the kind within the Labyrinth, and it was not until a portion of the largest boss was blasted off that it was found to have on it "G Knight, June 1, 1836"

The upper surface of both the Cave-earth and the Breccia rose, with some irregularities, 38 inches from the mouth of the Labyrinth to its innermost extremity, giving a mean ascending gradient of about 1 in 17

The total number of "finds" in this branch of the Cavern was 135, and the specimens they included were as follow —

Lying on the surface —Three portions of ribs and two other bones (No 6780), the two latter having been cut with a sharp tool, perhaps by an existing butcher, and one bone of Bat in a heap of "Pipes" of Stalactite, probably collected by man

In the Granular Stalagmite —One tooth of Lion

In the Cave-earth —32 teeth of Hyæna, 7 of Bear, 6 of Fox, 3 of Horse, 2 of Rhinoceros, 3 plates of a molar of a young Mammoth, 1 of Lion, 1 of Ox, and 1 of Sheep (of doubtful position), several bones and portions of bone, including a tarsus of Bird, and two pieces of bone apparently charred, 1 coprolite, and 1 small chip of flint

In the Crystalline Stalagmite —6 teeth of Bear, of which 5 were in one and the same jaw.

In the Breccia —215 teeth of Bear, and a considerable number of bones, of which many are good specimens

As in all other parts of the Cavern where he had made researches, Mr. MacEnery simply cast aside the material he dug up, without taking it to the exterior for final examination. The Superintendents took outside the Cavern the "broken ground" met with in the Labyrinth and examined it carefully by daylight, as in all previous cases of the kind It yielded 17 teeth of Bear, 14 of Hyæna (three of them in pieces of jaws), 2 of the Gigantic Irish Deer (in part of a jaw), 1 of Deer, 1 of Horse, 1 of Sheep; bones and pieces of bone; and part of a Crab's claw, no doubt quite recent

The exploration of the Labyrinth, commenced on October 28, 1875, was completed on July 10, 1876, upwards of 8 months having been spent on it.

Matthews's Passage.—Having finished their researches in the Labyrinth, the Committee proceeded at once to explore the small branch leading from it to the Bear's Den, and termed, as already stated, Matthews's Passage, thus leaving the two other and adjacent small ramifications to be undertaken on some future occasion To this course they were tempted partly on account of the severe and protracted labour which, from their very limited breadth and the character of their deposits, must attend the excavation of those branches, and partly by the wealth of osseous remains which, from Mr. MacEnery's description, they are likely to find in the Bear's Den.

Matthews's Passage consists of two Reaches. the first, opening out of the Labyrinth, extends for about 14 feet towards the south-east, where the second turns sharply towards east-north-east, and after a somewhat tortuous course for about 15 feet, enters the Bear's Den. Their height is from 9 to 10 feet almost everywhere (measuring, as usual, from the bottom of the excavation, which nowhere reaches the limestone floor), and they vary from 3·5 feet to 7 feet in width. The walls and roof, the latter especially, bear evident traces of the erosive action of a flowing stream, succeeded by the corrosion due, no doubt, to acidulated water, as the surfaces are much fretted. Holes, having the aspect of mouths of small watercourses, open out of the walls and roof in various places, and about midway in the Second Reach the roof rises into a small water-worn dome, from the apex of which a cylindrical flue ascends into the limestone, and, like the watercourses just mentioned, is quite empty.

There were but scanty traces of a Stalagmitic Floor in the First Reach, in which, however, the earlier explorers had here and there broken ground, but throughout the entire length of the Second Reach a Floor of Granular Stalagmite extended from wall to wall, varying from 10 to 24 inches in thickness, and at about 10 feet from its entrance there was also a portion of a Floor of Crystalline or old Stalagmite adhering to the left wall, whence it probably never extended to the opposite side. It was about 15 inches thick, below and almost in contact with the Granular Floor, but separated from it by a layer of Cave-earth about one inch thick

The mechanical deposits in the First Reach were the usual thin layer of Cave-earth above, and the Breccia of unknown depth below, but in the Second Reach the space beneath the Stalagmitic Floor was mainly occupied with large loose masses of limestone, some of which required to be blasted more than once in order to remove them The spaces between them were filled with Cave-earth or Breccia, with comparatively few specimens of any kind

The upper surface of the Cave-earth was almost perfectly horizontal in the First Reach, but in the Second there was a gradual and total ascent of 27 inches, giving a mean gradient of about 1 in 7 for that Reach.

Matthews's Passage yielded a total of 49 "finds," consisting of specimens which may be thus distributed —

In the Cave-earth —26 teeth of Hyæna (some of them in portions of jaws), 2 of Bear, 1 of an immature Mammoth, 1 of Fox, and a considerable number of bones, many of them being more or less broken and a few of them gnawed.

In the Breccia.—100 teeth of Bear and a large number of bones, including many good specimens The richest "finds" were met with in a small narrow recess in the outer angle at the junction of the two Reaches, where the teeth and bones lay huddled confusedly together, suggesting that a rush of water had probably carried them to the spot they occupied.

No trace of man was detected in any part of this branch of the Cavern.

The exploration of Matthews's Passage, begun on 11th July, 1876, was completed on 31st August, having occupied about 7 weeks. and operations were commenced in the Bear's Den on 1st September.

In looking over the work accomplished, and the discoveries made, since the Eleventh Report was presented at Bristol in 1875, the following noteworthy facts present themselves : —

1st In their Eleventh Report the Committee sketched the distribution in the Cavern of the remains of the various species of Mammals which characterize the Cave-earth. Of this sketch the following is a brief summary :—The Hyæna had been met with wherever the Cave-earth was found ; the Hare had not been detected anywhere in the "Western Division" of the Cavern—that most remote from the external entrances : the Badger, Wolf, and Ox had not been found beyond the "Charcoal Cave," and relics of Horse, Rhinoceros, Deer, Fox, Elephant, and Lion had not appeared beyond the "Long Arcade."

The discoveries which have since been made require that this sketch should be corrected in the following particulars:—Remains of Ox, Horse, Rhinoceros, Deer (?), Fox, Elephant, and Lion have all now been found beyond the Long Arcade, in one or more of the three branches of the Cavern explored since the Bristol Meeting. In all other particulars the distribution remains at present as sketched in 1875.

2nd. No tooth, or, so far as is at present known, other trace of *Machairodus latidens* has been met with since the last Report was drawn up. In short, the only evidence of the presence in the Cavern of this extinct species of Mammal which the Committee have detected during the continuous labour of almost twelve years, is the one solitary, but well-marked, incisor found 29th July, 1872—a fact well calculated to impress one with the unsatisfactory nature of merely negative evidence. It cannot be doubted that had this comparatively small specimen been overlooked, the palæontologists who, prior to its discovery, were sceptical respecting the occurrence of *Machairodus* in Kent's Hole, as stated by Mr. MacEnery, would have believed their scepticism to be strongly confirmed by the labours of your Committee, whilst the number of their followers would have been greatly increased.

3rd. As has been already stated, the Committee commenced the exploration of the Labyrinth on 28th October, 1875, and from that time to 31st August, 1876 (a period of upwards of ten months), they were occupied in it and in Matthews's Passage, both of which they completely explored, yet, during all that time, and in those two important branches of the Cavern, they found no trace whatever of prehistoric man. Had your Committee, on receiving their appointment from the British Association in 1864, commenced their researches in either of the branches just named (and such a course was by no means without its advocates), instead of beginning at the external mouth of the Cavern and proceeding thence steadily through the successive chambers and galleries, there can be little or no doubt that Kent's Hole would have been pronounced to be utterly destitute of any evidence on the question of Human Antiquity, and but poorly furnished with the remains of extinct Mammalia. The work would probably have been closed without going further, to the great loss of Anthropology and Palæontology, as well as of popular education in these important branches of science.

Report of the Committee, consisting of Prof. SYLVESTER, Prof. CAYLEY, Prof. HIRST, Rev. Prof. BARTHOLOMEW PRICE, Prof. H. J. S. SMITH, Dr. SPOTTISWOODE, Mr. R. B. HAYWARD, Dr. SALMON, Rev. Prof. R. TOWNSEND, Prof. FULLER, Prof. KELLAND, Mr. J. M. WILSON, Prof. HENRICI, Mr. J. W. L. GLAISHER, *and* Prof. CLIFFORD, *appointed for the purpose of considering the possibility of Improving the Methods of Instruction in Elementary Geometry, and reappointed to consider the Syllabus drawn up by the Association for the Improvement of Geometrical Teaching, and to report thereon. Drawn up by* Mr. HAYWARD.

IN a previous Report (Report for 1873, p. 459) the Committee recognized the fact that the main practical difficulty in effecting an improvement in the existing methods of teaching elementary geometry is that of reconciling the claims of the teacher to greater freedom with the necessity of one fixed and definite standard for examination purposes They also expressed their conviction that "no text-book that has yet been produced is fit to succeed Euclid in the position of authority," and that in the absence of such a text-book, whether the existence of a standard authority in the future such as Euclid has been in the past be regarded as desirable or not, it is important to secure "the requisite degree of uniformity and no more by the publication of an authorized Syllabus" of propositions in a definite sequence, which should be regarded as a standard sequence for examination purposes, and subject to which alone any amount of variety in demonstration and general treatment of the subject should be admissible

As it was understood that the Association for the Improvement of Geometrical Teaching was engaged in the task of drawing up such a Syllabus, no further action was taken by the Committee until the present year, when, the Syllabus having been completed and published, they have proceeded to consider the same in accordance with the instructions contained in the resolution reappointing the Committee

The Committee have not considered it to be their duty to examine the Syllabus in minute detail, but rather to report on its general character and its fitness as a basis for an authorized standard sequence of propositions

The Committee have no hesitation in stating at the outset, as the result of their *consideration* of the Syllabus as a whole, that it appears to have been drawn up with such care, and with such regard to the essential conditions of the problem, as to render it highly desirable that it should be considered in detail by authorized representatives of the Universities and the other great examining bodies of the United Kingdom with a view to its adoption, subject to any modifications which such detailed consideration may show to be necessary, as the standard for examinations in Elementary Geometry.

It may be well to observe that the adoption of this or some such standard Syllabus would not *necessitate* the abandonment of the 'Elements of Euclid' as a text-book by such teachers as still preferred it to any other, as it would at the utmost involve only such supplementary teaching as is contained in the notes appended to many of the editions of Euclid now in use; while it would greatly relieve that large and increasing body of teachers, who demand greater freedom in the treatment of geometry than under existing conditions they can venture to adopt.

Having thus expressed their opinion of the general merits of the Syllabus as a whole, the Committee have only further to add a few remarks on its more important features, which may serve to call attention to those points in which it differs from Euclid, and which give it a claim on the consideration of all who are interested in the improvement of instruction in Geometry.

1. *Geometrical Constructions.*

It has been found, in the experience of many who have taught Geometry to young beginners, that the attainment of a firm grasp of its fundamental conceptions and methods is much facilitated by a series of exercises in constructions made with the ruler and compasses, such exercises being given either as preliminary to, or simultaneously with, the study of the earlier parts of Theoretical Geometry. A judicious selection of such exercises is prefixed to the Syllabus, and the Committee remark with approval that here, as well as in the Postulates of Book I., the use of the compasses for direct transference of distances is formally admitted.

2 *Logical Introduction*

The Syllabus is further prefaced with an introduction, in which are collected together and formulated the most important logical relations of the several propositions logically associated with a given proposition, namely its *converse*, its *obverse* (sometimes called its *opposite*), and its *contrapositive* It is distinctly stated, in a note prefixed to this introduction, that it is not intended that a study of the abstract logical relations contained in it should *precede* the study of Geometry, but that the introduction should be referred to from time to time as instances of the applications of its principles arise, until the student obtains such a grasp of the principles and rules as to be able to apply them without difficulty With this understanding the Committee regard the proposed logical introduction as a valuable feature of the Syllabus

3 *Separation of Theorems and Problems—Loci*

Throughout the Syllabus, the Problems, instead of being interspersed among the Theorems, are collected together in separate sections at the end of each Book This may be regarded as equivalent to the assertion of the principle that, while Problems are from their very nature dependent for the form, and even the possibility, of their solution on the arbitrary limitation of the instruments allowed to be used, Theorems being truths involving no arbitrary element ought to be exhibited in a form and sequence independent of such limitations In other words, constructions may be rightly assumed in the demonstrations of theorems, whether or not they have been shown previously to be capable of being effected by ruler and compasses, provided only they can be seen from the nature of the case, or be proved, to be possible For instance, the existence of the third part of an angle being regarded as axiomatic, the impossibility of trisecting an angle with ruler and compasses only ought to form no obstacle to the proof of a theorem for which the trisection of an angle is required It should be remembered that the acceptance of the principle here asserted by no means necessitates *in teaching* that separation of Theorems from Problems which seems desirable in a syllabus It is probable that most teachers would prefer to introduce problems, not as a separate section of geometry, but rather in connexion with the theorems with which they are essentially related The Syllabus in this respect leaves complete freedom to the teacher

The early introduction of the notion of a Locus and its use in the solution of problems by the intersection of Loci the Committee regard with favour, and they observe with satisfaction that the Syllabus rightly insists on the demonstration of *two* theorems (a theorem, and either its converse or its obverse) as necessary for the complete establishment of a locus, a point which is too often neglected in the investigation of loci.

4 Book I *The Straight Line*

The Definitions are substantially those of Euclid An attempt to give a *real* definition of a straight line (Euclid's is only verbal) is to be commended, though the wording is difficult, and would for a beginner require detailed and familiar explanation.

The definition of an angle is another of the elementary difficulties of Geometry. The Syllabus in a note asserts that "an angle is a simple concept incapable of *definition*, properly so called," but enters into a somewhat detailed explanation in which the notion of rotation is freely but judiciously used The Syllabus does not (like Euclid) limit the notion of an angle to one less than two right angles, but it does not explicitly recognize an angle greater than four right angles. Possibly, considering the difficulties of expression which the complete notion of an angle of unlimited magnitude involves, this limitation at the outset is wise. The Committee note with approval the use of the term *conjugate* for the two angles which, being contained by the same pair of lines drawn from a point, together make up four right angles.

They also approve the introduction of the term "*identically* equal" for figures which, differing only in respect of position, can be made to coincide with one another, while the term "equal" is reserved for such as are equal in area, but not necessarily in other respects.

The Syllabus divides the Axioms (as, indeed, Euclid did) into General Axioms (Euclid's *κοιναὶ ἔννοιαι*), which find their fitting place in the Logical Introduction, and specially Geometrical Axioms (Euclid's *αἰτήματα*), which are nearly those of Euclid—that about the equality of right angles being omitted, while that asserting that "two straight lines cannot enclose a space" is extended so as to assert coincidence beyond as well as between the two points which coincide

The Postulates are those of Euclid's 'Elements,' with a modification in the third postulate, which admits of the direct transference of distances by the compasses, as before remarked.

The Theorems of Book I are mainly those of Euclid I 1–34, rearranged. The guiding principle of the rearrangement appears to have been the nearness or remoteness of the theorems from the possibility of proof by the direct application of the fundamental principle of superposition, the free use of this principle being indicated as desirable in many cases where Euclid prefers to keep it out of sight.

The discussion of the cases of identical equality of two triangles is rendered complete by the introduction of a theorem asserting the true conclusion from the equality of two sides and a non-included angle in each, namely, that the other non-included angles are either equal or supplementary, and that in the former case only are the triangles identically equal

For the treatment of Parallels, Playfair's Axiom that "Two straight lines that intersect one another cannot both be parallel to the same straight line," has been substituted for Euclid's twelfth Axiom, and, in the opinion of the Committee, judiciously It may, in fact, be regarded as merely an improved form of that axiom

5 Book II. *Areas.*

This book contains in thirteen Theorems the various theorems contained in Euclid between I 35 and the end of Book II. Beyond noting the fact that it brings together more completely than in Euclid those theorems which are naturally related to one another, no comment is necessary which is not of the nature of that detailed criticism which the Committee do not think it their duty to offer

6. Book III. *The Circle.*

In this Book the sequence of Theorems differs materially from that of Euclid, those propositions being placed first which are fundamental in the sense that they follow directly from superposition. Other criticisms which might be offered on this part of the Syllabus are chiefly on points of detail on which the Committee think it unnecessary here to enter

They would remark, however, with respect to the two modes of treatment of tangents in the Syllabus, that they would not recommend the second (depending on the notion of limits) in any case as a *substitute* for the first, however desirable it may be that it should be freely used by way of illustration and as leading up to the methods of Higher Geometry

7 Books IV and V *Ratio and Proportion, and their application to Geometry*

A theory of Proportion which shall be at once perfectly rigorous and complete is necessarily difficult The Committee recognize with satisfaction that the Syllabus does not attempt to attain simplicity by any sacrifice of rigour, nor in Book IV by any sacrifice of completeness In Book IV the theory is essentially that of Euclid in his famous, though (at the present day) little studied, Fifth Book it is suggested, however, by an unusually full indication in this part of the Syllabus of the forms of demonstration recommended, that his theory may be presented in a form more easy to be grasped and applied by the adoption of the late Prof de Morgan's notation, in which magnitudes are denoted by capital letters, instead of by straight lines and their multiples by prefixing to the capitals small letters denoting integral numbers instead of denoting them by longer lines Opinions will probably differ as to the wisdom of retaining Euclid's treatment in any shape*, but the Committee doubt whether any rival theory, which is *equally rigorous* and *equally complete*, would be more generally accepted

It may, however, be thought that this complete theory is one which the ordinary student can hardly be expected to master at an early stage of his mathematical studies, even though he may be well prepared for the study of the geometrical applications of the theory of Proportion At the same time it is undesirable that the study of Similarity of Figures &c should be commenced without some definite groundwork of demonstrated properties of Ratios and Proportions The Syllabus suggests a mode of meeting this difficulty by prefixing to Book V an indication of a method of treatment of the general doctrine of proportion, in which greater simplicity is obtained, not by the sacrifice of rigour, but by a certain sacrifice of completeness, in limiting the magnitudes considered to such as are *commensurable*

The notion of Ratio may be regarded as an extension and generalization of the notion of *quantuplicity*, the simplest expression of which is contained in the question "How many times does a magnitude A contain another magnitude B?" This question may be generalized so as to apply to any pair of *commensurable* magnitudes in two ways—the question taking the shape either "How many times does A contain some aliquot part of B?" or else "What multiples of A and B are equal to one another?" The former leads to a treatment of proportion such as is usually given with more or less exactness in treatises on Arithmetic or Algebra, while the latter leads to a treatment similar in principle to Euclid's, but simplified by its limitation to commensurables The Syllabus indicates a few of the more important general properties of proportion which ought to be proved by one or other of these methods, but leaves it open to the teacher to adopt whichever mode of treatment he may prefer

In the Geometrical Applications of Proportion the Syllabus groups together all the theorems which directly depend on the definition of proportion, indicating that the demonstrations are to be adapted to the complete or to the partial theory according as the one or other has been studied. After these follow the usual standard theorems on Similar Figures, &c., on which it is unnecessary for the Committee to offer any comment.

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* Prof Cayley is strongly of opinion that it ought to be retained

The Association for the Improvement of Geometrical Teaching has not yet published any Syllabus of Solid Geometry. Should the present Syllabus of Plane Geometry be successful in leading to the establishment of a standard sequence of propositions in that subject, it is to be hoped that the Association will continue its labours in the field of Solid Geometry, where the Committee believe they are equally needed.

Results of a Comparison of the British-Association Units of Electrical Resistance. By G. CHRYSTAL *and* S. A. SAUNDER*.

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

Difficulties encountered.—The difficulties of the kind of measurement we had to make are confined almost entirely to the temperature determinations. Were it not for these a much higher degree of accuracy could be attained; for while resistances comparable with the B.A. unit can be measured without difficulty to the 100,000th part, it is very difficult to determine the temperature of a wire imbedded in paraffin, as are the wires of the standards, nearer than the one tenth of a degree Centigrade, an error to which extent entails in some of the coils an error of ·03 per cent. of resistance.

A mere comparison of the coils at the temperatures given on page 483 of the B.A. Report on Electrical Standards (1867)† would hardly have been satisfactory, since it would have given no check on the accuracy of the observations and afforded no information as to the temperature value of a variation in resistance, and conversely.

Object aimed at.—The object aimed at in the experiments was to get the differences between the resistances of the several coils at some standard temperature, and also the coefficients of variation of resistance with temperature in the neighbourhood of the standard temperature.

That it is inadmissible to apply to any given coil the variation-coefficient for its supposed material, as found by Matthiessen and others from experiments on naked wires, is abundantly evident. This appears very strikingly in the case of coils Nos. 2 and 3 (A and B in our subsequent numbering), and an examination of the results of Lenz, Arndtsen, Siemens, and others for platinum shows that within certain limits its behaviour is very uncertain. This arises no doubt from the presence of more or less iridium or other platinoids, a small admixture of which, without altering the value of platinum commercially, affects its electric resistance very considerably.

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* In the spring of last year a series of experiments was made by one of the authors (G. Chrystal) with a view of comparing the different resistance-coils of the set of British-Association units formerly deposited at Kew Observatory and now in the Cavendish Laboratory at Cambridge. In the month of October a final set of experiments was made, which was the work of both of us, sometimes working together and sometimes separately.

† Or Reprint, p. 146.

Preliminary experiments.—The preliminary experiments gave the differences between the coils and the variation-coefficients approximately.

The results appeared in some cases different from former measurements, so that it was thought better not to rely on these, but to make a more careful set of experiments on which to found the final comparison.

Approximate coefficient of "Flat Coil" and Middle Coils.—The variation-coefficient of the "Flat Coil" was taken from the preliminary experiments. This was given by a fairly good series of experiments, and a first approximation was considered sufficient, since the coil during the final experiments never varied in temperature more than two degrees, being always bathed in the tap-water. A similar remark applies to the middle coils. The coils used for middle coils were 29 and 43 (F and G) when neither of these was being measured, in which case 2 and 3 (A and B) were used. The coefficients of these coils, so far as required for small temperature-corrections, were taken from the preliminary experiments.

Method of experimenting.—The method used in the final experiments was as follows:—

First. All the coils (the flat coil, the two middle coils, and the coil to be compared with the flat coil) were bathed in a stream of tap-water, the temperature of which was carefully taken by means of a Casella's thermometer (lent us by Mr. Gordon), reading to tenths of a degree Centigrade and easily estimable to hundredths. After the temperature of the stream had been constant for twenty minutes or so, the difference between the coil to be compared and the flat coil was found.

Secondly. Another series of experiments was made in which the flat coil and the middle coils were kept at the temperature of the tap as before, but the remaining coil was raised by careful nursing, which lasted two hours or more, to the temperature (or to one of the temperatures) at which, according to the B. A. Report, it is correct.

Lastly. The coils were compared with each other at the standard temperatures, the middle coils being kept at the temperature of the tap-water.

Variation-coefficients, how found.—The first two sets were used to give the variation-coefficients, being peculiarly fitted to do so, because in them the temperature of the flat coil did not alter much in comparison with the alteration in the coil compared with it.

Differences between the coils, how found.—Then using the low-temperature experiments the differences of resistance between the respective coils and the flat coil (all at 10° C.) were found.

Control experiments, how used.—From this, of course, the difference between any two coils at any temperatures could be calculated. This was done for the old standard temperatures, and the results compared with the results of direct experiment obtained from our third set of experiments. This gave a test of the accuracy of our work, and it is on this mainly that we rely in claiming to have stated the temperatures at which the coils are equal within 0°·1 C. in all cases.

Degree of accuracy.—The degree of accuracy of resistance varies, of course, for the different coils. For the platinum units 0°·1 C. corresponds to a variation of ·03 per cent. resistance, for the platinum-silver to about ·002 per cent.

In the B.A. Report, 1865 (p. 303)*, all the coils are stated to be accurate at the temperatures indicated within ·01 per cent. This corresponds to about one thirtieth of a degree Centigrade for the platinum units. It is not stated how this degree of accuracy was attained. Some such statement was perhaps necessary, considering the difficulty of controlling the temperature of an inaccessible wire, even within 1° Centigrade

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* Reprint, p. 137.

Arrangement &c. of apparatus.—The instruments used in these experiments for resistance measurements were the Wheatstone's bridge and Thomson's galvanometer belonging to the Association The arrangements in the low-temperature experiments were as in the annexed figure At one corner of a large

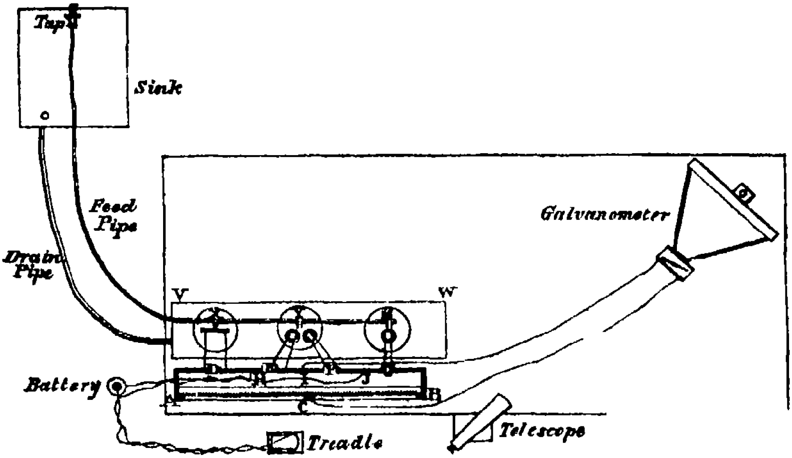

table is the bridge A B (see B A. Report, 1864, p. 353*), by means of mercury-cups at D and G, are inserted the flat coil and the coil being compared with it, at E and F are similarly inserted the middle coils, which were always two of the units, as small and as nearly equal in temperature-variation as possible. X, Y, Z are three earthenware jars in which the coils are placed; these stand in a trough, V W, provided with a waste-pipe going to the sink. The jars were kept constantly overflowing by means of a feed-pipe fitted with an offset for each. The temperature in all three jars was carefully observed, and it was found that after the tap had been turned on for fifteen minutes or so the temperature in all three in general became constant, and remained so within a tenth of a degree for a long time. Now and then irregularities occurred, which caused the rejection of the results concerned Thin wires go from E and from the contact-block C to the galvanometer at the other end of the table. The last adjustments of the balance were made by observing the spot on the galvanometer-scale with the telescope from where the observer sits. The battery-circuit terminates at H and J, and is made and broken by means of a treadle worked by the observer's foot. A small Leclanché's cell was found sufficient to indicate a deviation from balance of a tenth of a millimetre on the bridge-scale. Since the contact of the block-piece could not be relied on within less than this, no higher battery-power was ever used.

Thermoelectric disturbances.—To avoid thermoelectric currents, owing to the junction of copper with brass at the block, the button of the block-piece was never touched by the fingers, but always by means of two pieces of wood, which were exchanged now and again to prevent heating. It was found impossible to avoid this disturbance altogether, and accordingly the following mode of procedure was adopted —

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* Reprint, p 119.

Direct magnetic disturbances.—We first carefully investigated whether there was any direct magnetic effect on the galvanometer owing to the currents in the apparatus; this was done by simply short-circuiting the galvanometer No such effect could be detected Being assured of this, we always operated as follows —Threw in the galvanometer by pressing down the button, then allowed the needle to come to rest with the small permanent deflection due to the thermoelectric current If now, on pressing down the treadle for an instant, there was no motion of the spot, we concluded that there was a balance It is to be noticed that since we are near balance the battery-circuit is conjugate to the galvanometer-circuit, and that, therefore, making or breaking the battery-circuit does not alter the effective resistance opposed to any electromotive force, thermoelectric or other, in the galvanometer-circuit (Of this we also assured ourselves by direct experiment) Another advantage of this method is that it ensures the least possible use of the battery, and thus avoids disturbances from heating During our final experiments both of us had acquired by considerable practice an acquaintance with the indications of the galvanometer, which enabled us to adjust the balance quickly, and thus secure in greater measure the advantage above mentioned

Self- and mutual induction.—It is also worth remarking that from the way the B A unit coils are wound, and from the general arrangement of the apparatus, neither self- nor mutual induction could have any sensible disturbing effects in our experiments *.

Method of using bridge for finding coefficients of variation &c.—In finding the variation-coefficients of the coils the bridge arrangement was used in the way described in the Report on Electrical Standards, 1864 (p 353, &c); but in finding the difference between the resistances of two coils, the method described by Prof. Foster (in the Journal of the Society of Telegraph Engineers, October 1874) was used In this method the bridge is first read with the normal coil and the coil to be compared with it in one position, and then the coils are interchanged, the difference of the bridge-readings gives the required difference of resistance in units of the bridge.

Bridge-units.—The unit in which we shall state our results further on is the resistance of a tenth of a millimetre of the bridge-wire, which is a metre long and has a resistance of *about* 075 ohm.

Calibration of bridge and thermometer.—The wire was carefully calibrated, but no errors were found large enough to affect our results

The thermometer used was also compared with a standard thermometer belonging to the laboratory, and the corrected temperatures are in every case given. The degree of accuracy attained in this last comparison was probably about ·05 Centigrade

Description of coils in the case.—In the case containing the coils there are altogether fourteen coils. Five of these are multiples of the unit, viz. 2, 3, 5, 8, and 10, and have brass labels on them, but the inscriptions have never been completed by filling in the last two figures of the temperature at which they are equal to the standard. We have not been able to get any description of these whatever, and have therefore not measured them. Besides these there accompany the box two coils marked A and B, which are not units, and a flat coil described as a normal coil, besides a set of

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* Another precaution of less importance was to cover the platinum-iridium wire of the bridge with pieces of wood to screen it from dust and radiation from the body of the observer.

tubes for mercury units. The flat coil we used and found very convenient, both from its shape and on account of its small variation-coefficient, which was only 34 per deg. Cent. in the above-mentioned units.

The case contains altogether nine unit coils, viz. —

2 Pt Ir	Nos 2 and 3.
2 Au Ag	,, 57 and 58
2 Pt . . .	,, 35 and 36
3 Pt Ag .	,, 6, 43, and 29.

Of the first six, all except 57, which we have not measured, are mentioned at p. 146 of the Reports, but none of them have proper labels. All, however, were marked in some way or other so as to be identifiable. Of the last three all have labels, which are complete in 6 and 43. Nos. 6 and 29 do not appear in the Reports. The temperature on 43, which does appear, agrees with that given on p. 146. We used 29 as a companion middle coil to 43, because its variation-coefficient was small and nearly equal to that of 43; but otherwise we have not bestowed much care on it.

Coils measured.—The coils which we have measured are, therefore, 2, 3, 58, 35, 36, 29, 43. These we call for convenience A, B, C, D, E, F, G. The normal coil is the flat coil at 10° Centigrade. This temperature is chosen because it was the lower limit of the temperature of the tap-water, which varied on different days from 10° to 12°, though it was very constant during a good part of any one day. As far as our experience went, the use of a stream of tap-water was the best as well as most convenient way of reducing the coils to a known temperature *.

Results of comparison: the first statement.—The following Table exhibits our results in the way which lies nearest the method by which they were obtained:—

R stands for resistance of flat coil at 10° C.
X ,, ,, of the respective coils A, B, &c. at 10° C.
λ ,, variation-coefficients.

Coil.	λ.	No of results of which mean	Greatest deviation from mean	R−X	No of results of which mean	Greatest deviation from mean
Flat coil	34					
A	107	5	4	867	5	10
B	200	3	2	811	3	3
C	95	6	6	159	2	2
D	401	10	5	2071	5	24
E	393	3	4	1954	3	8
F	28	1		−82	1	
G	35	4	2	−57	2	0

Second statement.—The above is the most convenient form of representing our results; but for the sake of comparison we give also the following (Y now stands for the resistance of the coils A, B, C, &c., at the temperatures, or at some one of them, given at p. 483, B. A. Report, 1867 †):—

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* One of us, in endeavouring to find the conductivity of paraffin, has since found that the temperature of a wire imbedded in a much greater thickness of paraffin than there is in the B.A. coils, reaches the temperature of the tap-water in considerably less than an hour, the paraffin-jacket having been at a temperature of about 30° throughout to start with.

† Reprint, p. 146.

Coil.	Temp in Report	R−Y
A	16°·0	−315
B	15·8	−349
C	15·3	−344
D	15·7	−215
E	15·7	−286
F		
G	15·2	−239

It will thus be seen that B and C are practically equal at the temperatures given, while A does not differ very much from these. D and E are not very different *inter se*, but differ somewhat from the first three, while G, considering its small coefficient, is considerably out.

Statement of standard temperatures.—If we consider B and C to be right at the temperatures given above and reduce the others so as to be equal to them, we should get the following Table of standard temperatures:—

Coil	Standard temp
A	16°·1
B	15·8
C	15·3
D	16·0
E	15·8
F	19·4
G	18·2

Results of control experiments.—In the next place we give the results of our control experiments, in which the several coils were nursed to temperatures very near those given in the Report, and then compared with each other. The small deviations from the temperatures in the Report arise from thermometer corrections. The differences thus found are given side by side with those calculated from the data given above; the differences are given in the next column, and in the last the greatest possible difference, owing to an error of 0°·1 C. in temperature determination.

Coils	Temp		Calculated	Observed	Difference.	Maximum Difference
A	15°·89	B−A	34	20	+14	40
B	15·69	C−A	42	19	+23	29
C	15·20	B−C	−8	+2	−10	29
D	15·59	C−D	163	180	−17	49
E	15·49	C−E	132	119	+13	48
F	13·45	E−D	31	70	−39	79
G	15·11	C−G	100	102	− 2	13
		G−D	63	43	+20	44
		C−G	100	103	− 3	13
		C−F	156	150	+ 6	12
		G−F	56	50	+ 6	6

It appears, therefore, that the differences between the observed and calculated values are always less than what would arise in the most unfavourable case, owing to an error of 0°·1 C. in the temperature determinations.

Rough comparison of coefficients with Matthiessen's.—It is perhaps worth while to give the following rough comparison between the results for the variation coefficients which we have obtained in the neighbourhood of 10° C with the mean results of Matthiessen

	Per cent increase per 1° C	
		Matth
Pt Ir	1 0	0 [illegible]
Au Ag	071	06[illegible]
Pt	300	[illegible]5
Pt Ag	{ 0 [illegible] 0[illegible] }	031

There is no striking difference except in the case of Pt Ir where the alloy of which the coil is made must approach much nearer a pure metal than Matthiessen's alloy (33 4 per cent iridium) did

Discrepancy in Coil G with former measurements The only other point to which we have to call attention is the discrepancy between former and present measurements in the coil G, whose resistance seems to have gone down since it was last tested

In conclusion we venture to suggest two alterations in the construction of standard coils which, as far as our experience goes would be improvements

First to make them flat instead of cylindrical This would facilitate stirring when the coils are immersed in any liquid

Secondly, to insert as near the wire as possible a properly insulated junction of a thermoelectric couple the other junction of which should be fastened on the outer case of the coil Several of these fitted to each coil would do away with a great deal of the trouble and uncertainty attending the temperature determinations required in comparing and copying standards

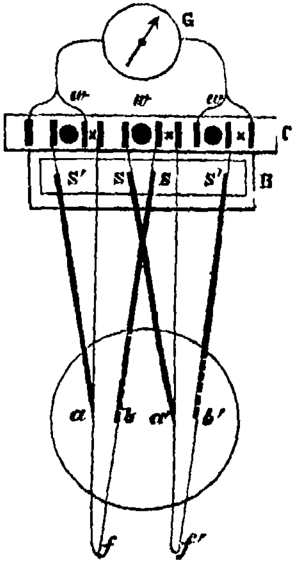
Third Report of a Committee, consisting of Prof A S Herschel, *B A., F R A S, and* G A Lebour, *F G S, on Experiments to determine the Thermal Conductivities of certain Rocks, showing especially the Geological Aspects of the Investigation.*

The object originally proposed by the Committee was to arrange and classify the most commonly occurring rocks experimentally according to their powers of conducting heat, and it has hitherto been so far successfully attained that the thermal conductivities of an extensive series of ordinarily occurring rocks have been shown to differ from each other on a very strongly marked scale of gradation, which it was endeavoured to represent graphically in the Committee's last Report by a series of ascending steps of absolute thermal resistance, or resistance to the passage of heat offered by the different rocks To every 200 units of this ascending scale a new letter of the alphabet, starting with A for the interval 0–200 of absolute resistance, was assigned, the values of the resistances were shown graphically, and the various rocks that arrange themselves under the several classes so formed could be readily discerned. By adopting this graphical mode of representation the values of certain

thermal resistances observed during the past year and communicated in this Report may be exhibited with equal clearness, and an easy comparison may by this means be made of the values found in this and last year's series of experiments where the same rock-specimens, or specimens of very closely allied kinds of rock, were submitted in the former and in this year's series to examination. A slight change, however, is here introduced in briefly describing the results obtained numerically, by employing, instead of the significant figures of those results (as was done in the last Report), the tenth part of them as a brief expression for the absolute thermal conductivity. Thus the absolute thermal conductivity of galena in the present list being 0·00705 in centimetre gramme second units hitherto described for brevity by its significant figures 705, will be spoken of in this Report as 70·5, to which the meaning may conveniently be attached that 70·5 gramme degree units of heat per second pass through a plate of galena one centimetre thick, having an area *of one square metre*, for a temperature-difference of one degree between its faces.

The method of investigation without the use of a thermopile has hitherto proved unsuccessful, no soft material capable of effecting a close junction with the rocks having yet been found of sufficiently constant resistance to afford a useful standard of comparison with them when the rocks are introduced between its layers; but the progress of the investigation has shown that a simple water-film (if it could be preserved from drying off with porous rocks) effects a complete junction between them and any impervious surface, as that of caoutchouc, against which they are pressed. A similar film of oil, it appears from some experiments recorded in the present list, is less effective for the purpose; and to ensure a constant water-film in which the thin wires of the thermopile could be placed, pieces of well soaked bladder kept soft in water rendered antiseptic with carbolic acid were laid on the india-rubber faces of the boiler and cooler, so as to press the thermopile-wires against the rock with a constantly moist and uniformly wet surface. The duration of an experiment and the temperature to which they were exposed (usually between 100° and 120° F.) were never so great as to cause the bladders to approach dryness before the termination of the experiment. The proportion of moisture absorbed by the rocks (when sensibly porous) was ascertained, and it was always such a small fraction of that imbibed by the same rocks thoroughly soaked *in vacuo* that it probably exercised a scarcely sensible influence on the results. Its amount, and that of the full quantity of water absorbable by the porous rocks tested, is stated in the list; and from the corresponding alteration of the observed conductivity some idea of the probable correction necessary to be applied for the presence of moisture in some of the porous rocks during the process of the experiment may be obtained.

The two chief defects of the thermopiles used hitherto had been their thickness (making them intrude too far from the rock surface into the badly conducting strata with which it is in contact), and the false thermoelectric currents proceeding from irregularities of material and internal condition of the wires subjected to great varieties of temperature along their length. To diminish the former source of error, wires less than half a millimetre (0·40 millim., or $\frac{1}{64}$ inch) in diameter were used and neatly soldered at the junctions, and to counteract as far as possible the remaining evil, they were chosen of the most dissimilar metals (iron and German silver), and twelve junctions above and twelve below the rock-plate formed a continuous circuit giving a very strong thermoelectric current. The whole resistance of the circuit (including the 20 ohms usually added to bring its indications conveniently within the scale of a Thomson's reflecting galvanometer) was 40 ohms when the wires were coupled for observing a difference of temperature; and it was assumed that, with this resistance and with the probable tendency of twelve wires similarly circumstanced to neutralize each other's false effects, no sensible errors from local disturbances would arise. The instrument was submitted to some careful tests, with a result that, at the highest temperatures of the experiments, errors in the temperature-difference amounting to about 1° F may have been committed. At the ordinary temperatures of the wires between 100° and 120° F it was found, by substituting a heated iron disk (coated on the faces with thin paper) in the place of a rock-plate, so as to heat both sets of wires equally, that the only permanent deviations produced as the plate sunk very slowly in temperature also sunk gradually with it from an equivalent value of about ¼° to about ½° upon the scale. As the correctness of the small temperature-differences (of 6° and upwards) lying usually between the above two temperatures was thus fairly checked, and for exceptionally higher differences and temperatures the conditions could not easily be more exactly assimilated to those of the actual experiments so as to control and estimate them, the effects of these small errors have not been further regarded in the calculations, but in order to avoid changes of value in the divisions of the scale, and to enable the actual temperature of each set of wire-junctions to be directly observed, an arrangement of the thermopile was made by which each set of junctions could be separately combined with a similar set in continuous circuit with the galvanometer placed in a small rectangular water-bath. The latter is made of tin, and, as well as its lid, is well jacketed with cork, and provided with an agitator, so that by adding hot or cold water, which can be withdrawn below, any temperature of the water in the bath can be obtained. A simple commutator enables the circuit with the galvanometer to be closed, either through the two principal sets of junctions or through one of them and through a set corresponding to it in the bath; so that by changing the temperature of the latter until no current passes through the circuit the actual temperature of each rock-face could be observed. This mode of observation is free from all objections, excepting those of false currents arising in long wires and plates of the same metal maintained at very various temperatures, but with the exception of the twelve loops of German-silver wire projecting on one side from the rock-plate, the corresponding loops on the other side, and all the rest of the circuits made to the galvanometer, were formed from the same piece of iron wire freshly annealed. The comb-like teeth of the commutator are pieces of narrow hoop-iron about 3 inches long, closely set together in wood, and also thoroughly annealed, to which the proper terminals of iron wire are soldered at their feet, while the upper ends are filed to chisel-edges; and a small hand-rack of iron wedges set on wood at proper distances apart, thrust between them in different positions, completes the connexion in the three different orders that are required. The additional branch wires used in the arrangement are few, and, as will be seen from the following description, add very little to the total lengths of iron wire which conduct the currents. The twelve-turn coil of wire in which the rock is pressed consists of twelve half-turns or loops of German silver and the same number of iron loops. The twelfth loop of German silver (see figure, p. 22) completes the circuit or connexion from the beginning to the end of the coil through the medium of the galvanometer. There are thus twelve junctions of dissimilar metals above, and twelve below the rock-plate in a closed circuit with the galvanometer. To produce a new set of twelve junctions corresponding to each of these, the loops of German-silver wire are all cut through in the middle, and the free ends soldered to twenty-four short pieces of iron wire, the junctions being laid side by side across a narrow water-tight trough formed of three or four rectangular washers of caoutchouc laid on a sheet-caoutchouc floor, upon which the sides of the rectangular tin bath, open at the top and bottom, are pressed down. The tin bath is 5 inches long (the same as the width of the rock-sections), nearly the same height, and 2 inches wide; and it is provided with a false bottom, through the perforations of which the water reaches the wires, and is kept agitated above by a thermometer passing through a longitudinal slit in the lid and attached to a small tin blade, without injuring them. The twenty-four extremities of iron wire projecting 1 or 2 inches beyond the bottom of the bath are there soldered to the feet of twenty-four teeth of the commutator, and the twelve iron wedges of the hand-rack being inserted between the points of these teeth, completes the circuit connexion in the ordinary way for observing a difference of temperature between the two principal sets of junctions of the thermopile. As a proof of the trustworthy action of the instrument, it may be mentioned that when, in the course of an experiment, the reading of the galvanometer with the thermopile thus joined up was being noted, and water of various temperatures from 60° F. to 160° F. was poured into the bath where the twenty-four supplementary junctions are placed and are all included in the circuit, not the smallest effect was produced upon the reading as soon as the water in the bath had by gentle agitation become uniform throughout in temperature. Not only are the two opposing sets of twelve junctions heated in the bath on the average all of exactly equal force, so as to balance each other, but the false currents, which in such ranges of temperature must be evoked with sensible intensity if any of them should prevail, either neutralize each other exactly or are entirely absent, as it appears equally probable to conjecture, in this portion of the apparatus. As regards formation of the circuit through one of the principal sets of junctions only, accompanied by a corresponding set of junctions in the bath, this is accomplished as is represented in the annexed outline sketch, where two pairs of junctions only (*a b*, *a' b'*), above and below the rock-plate, are shown, thin lines representing iron and thick lines German-silver wire. B is the bath in which the supplementary junctions, *s' s s s'*, obtained by severing the loops of German-silver wire, as at *s s*, are immersed. The two extreme half-loops and corresponding teeth of the commutator serve to complete the circuit with the galvanometer; and the arrangement for every additional severed loop of German-silver wire introduced between them will easily be apprehended from the single intermediate one, *s s*, here shown. The iron wedges, *w w w*, of the rack-piece pushed downwards between the yielding iron blades of the commutator are shown by black dots, forming a circuit in the usual manner for obtaining a reading of difference of temperature between the junctions *a a'*, *b b'*. Each loop or half-turn (*b f a*, *b' f' a'*) of iron wire is continued past



the upper junctions (a, a') and carried through the bath to a separate tooth of the commutator; and by moving the wedges of the rack-piece together one tooth-space to the right or left (as shown in new positions by a × in the figure), combinations of junctions in the bath with junctions ($a\,a'$) above or ($b\,b'$) below the rock-plate are put into connexion with the galvanometer.

By the same mode of trial as before, a heated iron plate coated with thin paper being substituted in the place of an experimental plate, the temperatures of its two faces, as exhibited by the thermometer in the bath when the commutator was shifted from one of its two supplementary positions to the other, were sensibly the same as the heated plate slowly cooled, and no false difference of temperature arising from false currents differently excited in the two circuits thus joined up were found to be indicated as a result of several such determinations of the really equal temperatures of the two faces of the plate This mode of observing the actual temperatures and the temperature-differences of the rock-faces in the present series of experiments was therefore constantly employed, and the values of the scale-divisions in degrees for the other more usual method of employing the thermopile were not determined with special care, although this adjustment of the commutator was also used to check and follow the gradual variations of temperature-difference that were less speedily, although more certainly, measured by the absolute method of determination. The only case of failure to observe a sensible difference of temperature between the two sides of an experimental plate occurred with iron-pyrites, which (as well as galena), being a good conductor of electricity, it was found necessary to coat with two thicknesses of the thinnest tissue-paper on each face, and the apparent difference of temperature recorded (which was decidedly less than 1°) may have arisen from the resistance offered by the slight obstructions of these thin paper sheets (soaked with water) to the passage of the heat. although certainly very great, no definite value of the thermal conductivity of ordinary iron-pyrites can therefore be assigned. It was also necessary to use oil junctions instead of wet bladders, from the galvanic effects produced by the saturated salt solution, when rock-salt was tested, and it appears probable from some measurements of quartz with the same kind of luting that the conductivity of rock-salt thus found is somewhat less than, rather than likely to be in excess of, the real thermal conductivity of that substance. As a good assurance that when membranes wetted with water were used to press the thermopile against the rocks the true temperatures of their faces were very nearly marked, the experiment with iron-pyrites may be instanced, as the small temperature-difference of less than 1° could not have been observed if the wires were not very nearly indeed at the same temperature as the two paper-covered faces of the pyrites against which they were pressed, and as the circumstances of their adjustment in other cases were exactly the same as in this instance, it may be assumed that the method of pressing the thermopile against the rocks with wet bladders adopted in the present series of experiments exhibited the true temperature-difference of the faces, and afforded correct values of the thermal conductivities The pressure was applied by means of strong spiral springs (instead of the weights described in the last Report), whose extensions in a graduated tube indicated the pressures which they were made to exert. The pressure thus applied was usually 80 lbs. upon a surface of nearly 20 square inches of the rock-plates, or about 4 lbs. per square inch. The general agreement of the results with those formerly obtained also serves to verify the correctness both of the thermal conductivities now assigned and of those previously observed. The principal differences in the two methods of determination consist in the use of an im-

Rock specimen tested 1876. (Water saturation *in vacuo*.)	Grains and per cent (on rock-weight) of water absorbed	Absolute conductivity observed		Absolute Resistance	Comparisons with former observations, 1875	
		Luting of Oil and Red lead	Wet bladder junction		Absolute Conductivity (1875)	Rock specimen tested (1875)
Rock salt (observed)		0·011[illegible]		87		
Do. allowing for radiation		0·0113[illegible]		88		
Fluorspar			0·00926	108		
Opaque white quartz		0·007[illegible]3	about 0·008[illegible]0	about 117 (?)	0·00880	The same specimen
Do. a new specimen		0·00[illegible]38		1[illegible]		
Galena (interspersed with a little quartz)			0·0070[illegible]	11[illegible]		
Pennant sandstone (near Bristol) thoroughly wet	80 grns = 1·3 per cent		0·00608	164	0·00[illegible]94	Kenton sandstone, thoroughly wet ([illegible]·7 per cent)
Do. dry			0·005[illegible]0	182		
Hard grit (Lee Abbey quarry, Linton, N. Devon) thoroughly wet	[illegible] grns = 6·3 per cent		0·0060[illegible]	16[illegible]	0·00[illegible]49	Do. dry (or moist by 1st experiment)
Do. moistened by 1st experiment	98 grns = 1·7[illegible] per cent		0·00[illegible]	177		
Festiniog slate (specimen A cut across the cleavage)			0·00[illegible]42	184	0·00[illegible]60	The same specimen
Festiniog slate (specimen A cut parallel to the cleavage)			0·00315	317	0·002[illegible]	The same specimen
Calcite (soft crystalline vein stuff in red sandstone, Clifton)			0·004[illegible]7	214	0·00462 to 0·00488	Various marbles
Trap rock, Pokham quarry near Exeter			0·00[illegible]8	272	0·00[illegible]32 0·00[illegible]6	Calton Hill Traprock Whinstone
Firebrick (fine ground, Newcastle) thoroughly wet)	859 grns = 17·0 per cent		0·00349	286	0·00247	Fine red brick thoroughly wet (15·6 per cent)
Do. moist by 1st experiment	132 grns = 8·6 per ct.		0·00174	575	0·00147	Do. dry (or moist by 1st experiment)
Cornish elvan (Christow Lead mines near Exeter)			0·00[illegible]94	340		
Clay-slate from same locality cut across the cleavage			0·00[illegible]8[illegible]	3[illegible]1		
Do. a specimen cut parallel to the cleavage			0·00268	373	·00363	Welsh slates cut parallel to the cleavage
Another do. do.			0·00262	382	·00325	
English plate glass		0·00204		490		
Heavy spar opaque crystallized (Christow, Exeter) two experiments			0·00186 to 0·00169	538 592	·00234	English alabaster (or gypsum)
Pumicestone thoroughly wet	1374 grns = 70·[illegible] p. ct.		0·00103	971		
Do. dry (or moist by 1st experiment)	110 grns = 5·6 p. ct.		0·00055	1818		
Newcastle house-coal			0·00057	1754	0·00065	Cannel coal.

proved thermopile, and in the substitution of wet membranes for the previously employed moist luting of wet linseed-meal in the present series. Where considerable discrepancies still exist, the discordance is rather to be ascribed to the numberless small precautions required to ensure perfect accuracy, than to any constant errors of the methods with which either of the two series of determinations is now believed to be affected.

In concluding this description, some remarks on the results of the new experiments that have been carried out will serve to show what new data have been obtained, and how far the observations made last year are corroborated and confirmed by the slightly modified apparatus and method of procedure that has been adopted to extend the series.

Among the points of principal importance noticed last year the following facts of great interest already ascertained have now been verified and confirmed. Quartz is still found to have about the same high thermal conductivity (85–88 concisely expressed, as explained at the beginning of this Report) compared to the other rocks which had been previously observed. The direction in which heat is transmitted through slate is a very important condition in regard to its conducting-power—the conductivity of good Welsh (Festiniog) slate cut across the cleavage being, however, to that of a plate of the same stone cut parallel to the cleavage planes, as 5·3 from this year's experiments, instead of 6·3 very nearly, as observed in the same slate specimens last year. The notable part of this difference of the two years' observations is in the better-conducting cross-cut plate (54 instead of 66), although the other less-conducting plate (31·5 and 32·5) has nearly the same conductivity as it appeared to have last year. Cleavage-fractures which the cross-cut plate has suffered, and their repairs, rendering its surfaces uneven and the water-junction contacts consequently somewhat imperfect, have probably caused this apparent loss of conductivity in the transversely cut specimen of slate. But this latter still exhibits a much higher thermal conductivity than that shown by the plate from the same piece of slate cut parallel to its cleavage-planes. A less distinct difference was found this year in similarly sawn and tested plates of clay-slate cut across and parallel to the planes of cleavage or of foliation; but the stronger kinds of the stone which supplied a transverse section (as well as the less fragile plates cut parallel to the planes of cleavage) presented the appearance of cleavage and foliation only very imperfectly, and much less remarkably than the specimens of ordinary slate from Wales. The thermal conductivity of the soft clay-slate is also less in all directions (26–28·5) than the least observed conductivity (31·5) of Welsh slate cut parallel to its cleavage-planes.

The observations of the effect of moisture in increasing the conductivity of the porous rocks, when thoroughly saturated with water, entirely corroborate the similar observations made last year. When the great pressure required to force a sensible quantity of water through such rocks as sandstone and others which were tested is compared with the very feeble currents which differences of temperature and of density of the water in their cavities can produce, it appears evident that the very marked increase of conductivity observed in such cases cannot be owing to convection- or gravitation-currents in the water which the saturated rocks contain, although the mobility of the liquid by diffusion and consequent intermixture of its molecules probably assists the direct conducting-power of water in the transmission of the heat; and the resulting conductivity of water, free from the action of convection-currents, appears to be at least equal to that of some rock-species whose thermal conductivities are either the last or nearly the lowest in the present list.

The thermal conductivities of certain new species of rocks are now also assigned, the values of which, although they are few in number, appear to possess considerable interest from a mineralogical as well as from a geological aspect. Some crystalline rocks and minerals of simple composition (and of the cubic system of crystallization) were selected, and, like quartz, they proved to have heat-conducting properties in a high degree. The thermal conductivity of iron-pyrites, resembling apparently that of the metals, could not, from its high value, be accurately determined by the method of experiment pursued; and it is accordingly omitted (as undetermined) from the list. The diathermancy of rock-salt for the heat radiated and absorbed by the oiled surfaces between which the trial plate of it was placed will not account for more than $\frac{1}{50}$ part of the heat which the plate actually transmitted; and the high position of this substance in the list is consequently due to a really high conductivity which rock-salt possesses (about 113), greater than that of quartz (85·88), and even of fluorspar (92½), the substance found to rank next to it in high conducting-power. A specimen of galena nearly pure, but enclosing a few fragments of quartz, presented the highest thermal conductivity (70½) next to that of quartz. A plate of soft, white, opaque calcite, perfectly but irregularly crystallized (forming vein-stuff in Clifton sandstone), agrees exactly in its thermal conductivity (46·7) with various kinds of marble (46–49) which were tried last year. On the other hand, a similar specimen of heavy spar (barium sulphate) from a mine of that substance near Exeter presents, in spite of its great density, a remarkably low thermal conductivity (17–18 in two experiments), not very far removed from that of English alabaster (gypsum, or calcium sulphate, 23·4). English plate-glass (20·4), it may also be remarked, has a low thermal conductivity, differing not very greatly from those of the two substances last named. Finally, the lightest species of rocks examined in the course of these experiments, pumicestone and Newcastle house-coal, have also the lowest conductivities (5·5 and 5·7) hitherto presenting themselves in these investigations.

As, with the exception of rock-salt, clay-slate and elvan, house-coal and pumicestone, no new thermal resistances of great importance, in a geological point of view, are added in the present list to those already exhibited in the diagram of these Reports (vol. for 1875, p. 59), a new graphic representation of the resistances now found is here deemed unnecessary—the values of the absolute resistances furnished in this Table enabling them to be added without difficulty in that diagram, where they may thus be exhibited in the same normal scale with the earlier determinations.

The applications to questions of underground temperatures which these observations suggest have not yet engaged the Committee's attention sufficiently to enable them to arrive at definite conclusions certain enough to entitle them to be noticed in this Report. Examples of very reliable measurements of underground temperatures, such as have recently been obtained in the tunnels of Mont Cenis and of St. Gothard, and in the deep vertical boring at Sperenberg, near Berlin (the last of which, although extremely deep, passes almost entirely through rock-salt), are ill-adapted to test distinctly the relative values of the thermal conductivities of different species of rocks—the former two from the irregular surface-configurations, and the last from the absence of any change of the strata through which these borings pass. In view also of the many disturbing conditions that affect both the local rate of change and the actual observations and measurements of underground temperatures in other borings more suitably adapted to exhibit clearly the differences of thermal resistance in geological formations, which the Committee is endeavouring to distinguish and to recognize in actual cases, it would be premature, in the present stage of the investigation, to deal more particularly with results derived immediately from these and from similar comparisons, the degree of dependence to be placed on which cannot very easily be defined The agreement which they trust eventually to trace between the observed temperatures and the experimentally determined thermal properties of the locally predominating rocks is liable to be masked and concealed by causes of disturbance of so many unknown and unsuspected kinds, that plain and obvious corroborations are not frequently to be expected, and the nature of those causes which principally tend to disturb the results will probably become better known by the progress of further comparisons such as the Committee is now endeavouring to pursue While it was thus anticipated by Prof Everett*, from the slow rate of temperature-variation from the surface observed in the rocky excavations of the Mont-Cenis tunnel, that quartz (which is a principal ingredient of the rock) would prove to have a high thermal conductivity, this property is now also found to belong to rock-salt, through which the Sperenberg boring passes with an average rate of temperature-variation (1° F in 51 English feet) scarcely differing sensibly from the mean rate obtained from a mass of similar observations taken in other places and recorded by the Underground Temperature Committee. The apparent contradiction presented by these two cases may possibly proceed from a more rapid local rate of variation of temperature in the neighbourhood of Sperenberg than around Mont Cenis, and the fact that in the first 60 fathoms of ordinary strata overlying the rock-salt the observed rate of variation was slower than below (contrary to what would be expected from the relative conductivities of the superincumbent strata and the underlying masses of rock-salt), is said, in Herr Dunker's description of the observations, to be probably accounted for by the intrusion into the boring near its mouth of the waste warm water of the engines on the surface The effect, it may be observed, of a highly conducting mass, like that of the deep bed of rock-salt here penetrated, by diminishing the local resistance and increasing the flow of internal heat outwards through the Sperenberg strata, would be to cause the local rate of variation of temperature in this locality to be abnormally rapid, and perhaps this may explain why a slow rate of variation is not observed in this instance, from the great depth of the excellently conducting rock-salt formation, which considerably exceeds 3000 feet The Sperenberg boring thus presents examples of secondary conditions which will perhaps prove to be in good agreement (instead of, as they at first appear to be, somewhat at variance) with the results of the Committee's observations.

Report of a Committee, consisting of the Right Hon. J G. HUBBARD, *M.P* , Mr. CHADWICK, *M.P.*, Mr. MORLEY, *M P.*, Dr. FARR, Mr. HALLETT, Professor JEVONS, Mr. NEWMARCH, Professor LEONE LEVI, Mr. HEYWOOD, *and* Mr. SHAEN *(with power to add to their number), appointed for the purpose of considering and reporting on the practicability of adopting a Common Measure of Value in the Assessment of Direct Taxation, local and imperial. By* Mr. HALLETT, *Secretary.*

YOUR Committee, appointed to inquire into the subject of a Common Measure of Value in Direct Taxation, have proceeded in this inquiry, have considered the matters to them referred, and have agreed to the following Report :—

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* See these Reports, vol. for 1875, p 16, note at bottom of the page.

1. *Measure of value wanted.*—The question of a common measure of value is one of a class that may be literally called standard questions, and its solution is at the basis of equality in taxation both general and particular. Values are the object matters of taxation, their measurement and comparison are the necessary condition of its equal incidence; and measurements with unequal measures are like weighings with unjust balances. Taxation, however pure its intention, without a common measure of value, is what navigation would be without sextant and chronometer, or architecture without compass and level. And this perhaps is not an unfair description of what it actually is, though not, it may be hoped, of what it must be. One of the chief marks of advancing science has been a progress towards better measures and better measurements, a substitution of the uniformities of rules of reason for the unrestricted vagaries of rules of thumb; and such is the aim of the present inquiry. This question of a common measure of value is the question of the common measure of taxation; or if there be several such measures, what is their common ratio? what are they in terms of one another?

2. *Two Methods of General Valuation: Capital Value and Usable Value.*—Measurements of the value of things (employing this word "things" as inclusive of land, labour, stock, &c.) may have reference to their absolute worth or to their temporary uses. They may have reference to their property, capital, or absolute values; or to their products, profits, or annual values. The one measure is exemplified in contracts of sale and purchase, the other in contracts of letting and hiring. Each has its special advantages and special applications. Capital or absolute value is applied in the assessment of probate and legacy duty; usable value in the assessment of local taxation and in those of the imperial income tax. Moreover, as the capital-value of the thing must be equivalent to the present value of the sum of its future uses, the two measures, if consistently defined, though differing it may be year by year, must be in the long run equivalent. But such consistency of definition is an essential. The idea of capital value is tolerably well fixed, but that of usable or lettable value is indefinite. Usable value is, or is equivalent to, the consideration paid for, the income received from, the use of things. This consideration, however, may be paid under such totally different conditions of contract that, unless these conditions are first assimilated, the payments regarded as measures, either of the values of the things or of the abilities of their owners, are worse than useless: they are misleading.

3. *Usable Value unrestricted and indeterminate and hence unfit as a common measure.*—To illustrate this: things having a use, and hence capable of becoming sources of income, are all, by the very nature of the process, liable to outgoings, some more, some less. Production involves productive consumption. Efficiency implies cost—cost, for the most part of insurance against natural risk, of repairs, of necessary depreciation. But the user of a thing, be it land, labour, or stock, may engage for its use with or without liability to these outgoings: their costs may be borne by the user or by the owner, or they may be divided between the two in any proportion that convenience may direct. The user may bear repairs and the owner natural risk and depreciation, or the user may bear natural risk and repairs and the owner natural depreciation, or the user may bear all and the owner none, or the user none and the owner all, the consideration given (the income received) of course varying accordingly. Were the things valued by absolute sale or capitalization, all the incidents, whether of efficiency or cost, plus or minus, would be wholly and uniformly included, and the test would fix the things' relative positions. In valuation by uses, however, it is evident that these

incidents are not as a matter of practice uniformly included, and the valuation, founded upon unfixed conditions, can fix nothing, its possibilities of variation are coextensive with those of free contract itself, and hence, being absolutely unrestricted, as a measure it must be inherently unfit

4. *Exemplified in incomes of Income-tax* —Such valuations, some tempering effect of deductions notwithstanding, have been those of local taxation, and hence the local chaos which Mr Sclater-Booth's bill was the last attempt to reduce to order. Such also, without any tempering influence, are the valuations of income under the present income-tax In this latter the returnable and taxable incomes of interest, land-rent, house-rent, royalties, wages, including professional fees and salaries, are the considerations that are paid for the uses of principal monies, land, houses, mines, and labour respectively Interest, however, is the consideration paid for the use of the principal, neither user nor owner being subject to any outgoings. Land-rent is the consideration paid for the use of land, the user bearing almost all outgoings House-rent is the consideration paid for the use of houses, the owner and user sharing the outgoings in various proportions The owner also largely bears outgoings in the contract of mines and royalties, he wholly bears them, as a rule, in that of labour and wages Moreover these outgoings vary according to the nature of the thing, they may vary from zero up to 40 or 50 per cent., or even more, of the gross production It is these differences that give rise to the various characteristics of incomes, as gross, net, certain, precarious, terminable, permanent, nominal, real. All, indeed, are in the catalogue of considerations paid, all are so-called incomes received, but only

> "As hounds and greyhounds, mongrels, spaniels, curs,
> Shoughs, water-rugs, and demi-wolves are cleped
> All by the name of dogs"

The true account "distinguishes" we are told, and gives to each "particular addition." the measure of incomes, too, that lays claim to scientific truth must do the same, and to the "bill that writes them all alike" and taxes them all alike, must add natural differences and just discrimination

5. *Usable value specialized and determined as Interest-value By consistent deduction of outgoings. Interest-value as the common measure required.*— And if the cause of these inequalities of valuation be rightly stated, the discovery of such measure ought not to be difficult. As the inequalities arise from the different conditions in respect to outgoings under which the various incomes are calculated, the remedy must be the assimilation of these conditions; and the case of principal and interest, which in one aspect may be regarded as a common expression of sources and uses generally, may be employed as a precedent. Interest, as before said, is the income received from a thing free of outgoings It leaves the thing or its capital value unimpaired. The extension of this idea to revenues or incomes in general is simply the universal deduction from them of their productive outgoings— equivalent to the general restoration of the capital-values of their respective sources Under such a regime, returnable and taxable income would *not* be land-rent, house-rent, mine-royalties, labour-wages; but land-rent *minus* land-outgoings, house-rent *minus* house-outgoings, mine-royalties *minus* mine-outgoings, labour-wages *minus* labour-outgoings; and similarly with terminable annuities and the profits of business, the outgoings, however, being in all cases only the *necessary* ones of the production. The result thus obtained would be what by analogy we may call the interest-value of the various sources; and such interest-value of land, of labour, of houses, of

economic agencies generally, would be the common measure required. And the measure is a perfectly scientific one, and, indeed, admits of mathematical expression. As the exact difference, comprehensively considered, between the total receipts and total outgoings of a source, it is the pure annual increment of its capital-value, and hence is identical with absolute profit. It would represent the pure annual growth of national wealth taken in its widest sense, and the returnable income of national taxation.

6. *Precedents for its practicability*.—But are such deductions of outgoings on the sources of income and the determination of the interest-value practicable? In many cases this question has been already solved by actual legislation. That such deductions are practicable for lands, houses, and mines may be proved by reference to the Metropolis Valuation Act of 1869, and to the Local Valuation Bill before referred to, both of which are grounded on them, and have schedules of deduction for different cases attached. That they are practicable for machines, ships, trade fixtures, horses, and stock generally, the Income-tax Act, with its special clauses for repairs and re-supply, itself recognizes; and though no schedules or deductions are attached for these cases, the deductions are well known in the estimates of business and recognized in the Surveyor's office. But if such deductions of outgoings are practicable for the labour of horses, are they not practicable for the labour of men? Economically considered, the two labours are analogous; both are productive agents, both have productive powers subject to consumption. Natural risk, maintenance, and terminability belong to the labour of men just as they belong to the labour of horses, just as risk, repairs, and terminability belong to machines, ships, or implements. All these outgoings are facts equally ascertained by experience, and it is difficult to see why their valuations are not equally practicable. They are as much an item in a source's general account as the receipts themselves, forming its debit as these form its credit column. Nor can any account, be it individual or national, be said to be complete unless both sides are considered.

7. *Effect on Income-tax Act*.—The application of this interest-value measure to the Income-tax Act would give these results:—Incomes from lands, houses, and mines would be charged much the same as under the proposed new local valuation system. Dividends and profits of capital, purely considered, would be charged as at present. Government and other terminable annuities would not be taxed on the amount representing the restoration of capital. On the same principle the incomes from labour, whether pure, as in the case of salaried officers and some professors, or mixed with the proceeds of capital, as in other professions and as in businesses, would be entitled to material deductions varying with the relative proportions of skill and capital engaged. In all cases the tax would be collected at the source and levied on the net value of the produce, and the deductions would be made without reference, as such, either to the position or fortune of the owner.

8. *Practicability exemplified in composite incomes*.—Questions may be raised on the practicability of applying an outgoings deduction to incomes from businesses and professions which are the mixed results of labour and capital. It may be objected either, first, that as labour and capital enter into these mixed incomes in varying proportions, and as the percentage of labour-outgoings is very different from that of capital-outgoings, a deduction common to these mixed incomes and to unmixed labour-incomes would be unjust; or, secondly, that if the labour-income and capital-income be assessed separately a separate return of capital will be necessary, and that this must entail an objectionable exposure of affairs. To meet the first objection, a classification

of business and professional incomes, with a varying percentage deduction according to the average proportion of capital in each class, has been proposed, but it may be doubted if the second objection has any just foundation. That the assessment of an income from conjoint sources does not necessarily involve an official return of these sources, may be seen by looking to the return of the income of capital or stock itself, as exemplified in all large trading companies. This income, regarded in the concrete, consists of the conjoint incomes from houses, ships, machinery, stock, trade fixtures, all of which incomes having different outgoings, are singly and differently assessed by the owner, but all of which are united, without statement of particulars, in one common official return. What is practicable, however, with the incomes (derived, say, from horse labour *plus* machinery) is also practicable with those derived from human labour *plus* capital generally Doubtless, in order to value the labour-income separately from the capital-income, the two must be separately known to the valuer, but not, therefore, separately returned to the Government unless Government undertakes the work of accountant The distinction between the two (the one technically known as profits, the other as interest) is a primary distinction in book-keeping usually given in every profit and loss account Capital being known (and this knowledge is as necessary to the preparation of an accurate return under the present system as to that under the proposed one), its interest subtracted from the mixed income will give the technical profits, gross labour-income, or gross wages of the capitalist The deduction of labour-outgoings from the labour-income will give the labour's interest-value, which, *plus* the interest of the capital, will be the interest-value or returnable income of the business or profession

Example 1 —A (a barrister, physician, or salaried officer) has £1000 a year, an unmixed gross labour-income. Assuming, *e g*, 40 per cent. to be the average labour-outgoings for risk, maintenance, and "depreciation," the deduction will be £400 and the interest-value £600. A's returnable and taxable income will be £600.

Example 2 —B (a solicitor or general medical practitioner) has £2000 capital in his practice, and a gross income as now returnable of £1000 a year, the joint result of his personal labour and his capital. Interest being reckoned at 5 per cent, £100 will be the interest-value of his capital, and £900 the gross income, wages, or so-called profits of his labour. The deduction of 40 per cent. from this for labour-outgoings leaves £540 as the labour's interest-value, which, *plus* £100 as the interest of capital, gives £640 as the interest-value of his practice. B's returnable and taxable income will be thus £640.

Example 3 —C (a merchant, manufacturer, or shopkeeper), having a capital of £10,000 in his business, has a gross income of £1000 a year, the joint result of his capital and personal labour. Here, under the former suppositions, the interest of his capital will be £500, and the gross income of his labour will be £500. Deducting 40 per cent. for labour-outgoings, as before, we obtain £300 as the labour's interest-value, which, *plus* the interest of the capital, equals £800, the interest-value of the business. C's returnable and taxable income will be £800.

Zero-point of Direct Taxation —In the remuneration of labour, as we descend in the scale, there must be a point at which income and outgoings balance, and at which, therefore, interest-value or real profit is zero. This important point in labour, analogous in land to the commencing point of rent, is the scientific division in labour between exemption and taxation that a common measure of value determines Wherever the point may be, below it there is no interest-value, and hence ought to be no taxation, and it is above this point that in strictness the percentage deduction for outgoings ought in every case to begin

Example 1 —A, a labourer, earns 30s per week, an unmixed gross labour-income. Assuming this sum to be only sufficient to meet the necessary labour-outgoings, then the interest-value of the income will be *nil*. A's income will be wholly untaxable.

Example 2 —B, a clerk or artisan, earns £150 per year Assuming, as before, 30s per week or £78 per year, as the necessary labour-outgoings, then the subtraction of this sum will mark the zero-point of the labour's taxable income, and £72 will be the margin to which alone the percentage deduction for outgoings ought to be applied Assuming this deduction at 40 per cent as before, we have £22 as such deduction, and £44 as the labour's interest-value B's returnable and taxable income will be £44

A similar preliminary process of correction applies to all higher labour-incomes, the zero-point being determined by the amount fixed on as the labour's necessary outgoings

9. *Proposed new Valuation System intermediate to the Self-assessment and Official Systems.*—The practical working of a measure of value, like other measures, has necessarily a relation to the persons by whom it is applied A just measure, through careless or wrong application, may act unjustly, but unjust application is no argument for an unjust measure, an unjust measure even when rightly applied must act unjustly. In the income-tax, as now arranged, with its five or six inconsistent measures of value, the valuation for some of the chief schedules ranges between the loose liberties of self-assessment and the inquisitorial stringency of official the one system conscious of a radical injustice in the law, which it is itself called on to apply, the other in total ignorance of the facts which the law covers, and both working in antagonism to each other In the valuation for probate duty we have a third system, applied not by the interested individual nor by the official, but by a third and independent party, authoritatively licensed, indeed, by the Government, but selected by the individual, and hence whilst neutral himself, having responsibilities to each Under an equitable measure of value, self-assessment might in the first instance exist as at present, but in cases of doubt Government might require the guarantee of such an independent authority (licensed valuer, accountant, lawyer, acting as a semiofficial commissioner in income-tax) for a second evidence to the truth of the return, reserving its own power of official examination as a last resort At the present time many firms do actually call in professional accountants to make up their returns, and with a growing sense of justice in the tax, such an independent guarantee to the truth of the return might not improbably become general, and might even acquire the force of a custom.

COMPARISON BETWEEN CAPITAL-VALUE AND INTEREST-VALUE.

10. *Capital-value and Interest-value equivalent on a series of years, but not for each year.*—The two measures, capital-value and interest-value, are, as before observed, on a series of years equivalent Interest-value is capital-value for a year. Capital-value is the present worth of interest-value for all

years. But though the two measures are thus equivalent on an average of years, they are not equivalent for each specific year. Interest-value measures the gains of capital for one year, and capital-value measures its gains for that year, with the expectant or probable gain of future years added. As, however, national gain for any year has, as a rule, the closest relation to the national expenses for that year, the interest-value is a more specific measure for annual taxation than the capital-value, and this is probably the reason that has unconsciously led to the adoption of an annual-value measure, both in local and imperial taxation, in preference to one of capital or perpetual value.

Capital-value in comparative relation to things and to tenures generally.—Measures practically equivalent may, however, through differences of application, give contrary results; and of this the two measures in question afford illustrations. Taxation, according to capital-value, may look either to the sources, things, or objects owned, or to the rights and tenures of their owners—to the land, labour, or stock possessed, or to the freehold, leasehold, life-tenancy, or jointure, as the case may be, of the possessors. *Primâ facie* it would appear that as the value of the tenures of a thing, however manifold, can be neither more nor less than the value of the thing itself, the results of the scientific capitalization of the two should be identical. As a matter of fact, however, this has not been admitted to be the case, and it is on the question of tenures that the deepest controversies of the income-tax have arisen.

Capital-value in relation to terminable tenures.—As the capital-value of a limited tenure in an estate, for example, is less than that of a permanent one, its taxation, it is argued, ought to be less, and therefore it ought to pay at a lower rate. Putting aside for a moment the question of the truth of this inference, it is evident that its enforcement would make an estate's taxation vary with the character of its tenure, thus giving power to the subject to alter taxation by altering tenure, and that to almost any extent. To avoid this it has been proposed to derive the whole tax from the estate as at present, but to levy on the limited tenure according to its capital-value, and to make the reversion liable for the balance.

Terminability of tenure does not influence the Annual Tax.—Without discussing the administrative difficulties of this view, it may be questioned whether such a view be a logical deduction from the principle of taxing tenures according to their capital-value. Assuming that a limited tenure in an estate ought to pay *less* than a permanent one, with reference to its capitalized value, it would not therefore follow that it ought to pay at a *lower annual rate.* Be the tenure long or short, the estate for any given year is the same, the value for that one year's tenure is the same, the government protection afforded to it for that year is the same, and hence it would appear that the payment for each year ought to be the same also. But if each year's payments be the same in both cases, the total payments are not therefore equal; the limited tenure pays only for a limited time, whilst the perpetual tenure pays for all time; and if these payments be aggregated it will be found that their amounts are in exact proportion to the capital-values of the respective tenures. Should it be said that the reversioner, having interests in the good government of the present, ought therefore to contribute according to the value of those interests, the reply is that the present possessor has been the reversioner of the past, and has had similar interests in the good government of the past. If, therefore, present possession has a claim on the future, it owes a debt to the past; and it may be mathematically shown, what perhaps a sense of the fitness of things indicates, that for any given year the claim and debt will cancel each other, and leave every year's possession to pay the whole year's tax on the estate possessed.

Difference between incomes from terminable tenures and those from terminable things.—That a terminable income by paying at the same annual rate as a perpetual income is equally paying according to its capital-value, is a proposition insisted on by Mr. Warburton and by Mr. Mill in the two Commissions on the Income-tax, and as far as the above class of terminable income is concerned, the proposition is true. But these gentlemen unfortunately carried it into a region where it had no status, and in virtue of it denied the applicability of capital-value, if not of arithmetical proportion generally, as a reforming measure of the income-tax. As there are incomes and incomes, so there are terminable incomes and terminable incomes. If the terminable income be the terminable tenure of a pure interest-value, such, practically speaking, as a life-interest in land or in consols, to tax it at the same rate as a permanent income is to tax each according to its capital-value. If, however, the terminable income be an income that is made up partly of interest-value and partly of capital that terminates, not simply as a legal right, but by gradually exhausting its source, then to charge such income at the same annual rate as a permanent one of similar amount is not to tax it according to its capital-value—a truth repeatedly demonstrated by the actuaries before Mr. Hume's committee, and evident from the reflection that the capital-value of the source is, by the very nature of the income, continually passing away, whilst the tax remains the same. Under the conditions stated, the tax on the one terminable income would be a tax on pure interest-value, the tax on the other would be a tax on a mixture of interest-value *plus* capital. By combining the propositions of the actuaries and of Mr. Warburton, each true in its own sphere, but each erroneous when applied to the other, we may conclude that the results obtained from the capitalization of tenures are identical with those obtained from the absolute valuation of sources; and both may be quoted in confirmation of those obtained from the principle of interest-value.

Capital-value in relation to personal riches and property. Common measure of value as needful for equal exemption as for equal taxation.—Another application of capital-value as a measure, however, cannot be so quoted. The taxation of a particular property according to capital-value may be interpreted as taxation, not according to the worth of that particular property, but according to the absolute worth or financial position of the person who owns it; and such a method of levy has been erroneously defended as taxation according to ability. In this view a rich man ought (considerations of practicability apart) to pay a heavier duty upon his dog, his bottle of wine or whiskey, than a poor man; and, the estates being equal, the owner of a permanent tenure would pay more for each year's possession than would the owner of a limited one. Such a theory of capital-value may not be general, but it has a certain degree of popularity, and seems to be constantly getting itself mixed up not only with discussions but even with legislation on the incidence of the income-tax. It may be questioned whether the operation of this theory is not visible, for example, in the exemption from imperial direct taxation (recently so largely extended) of large masses of property in the country including many thousands of acres of land, in consequence of the accident of their ownership. Property thus exempted becomes property taxable by mere change of possession, irrespective of the intrinsic nature or value of the property itself. To exempt in an income-tax the necessary outgoings of the source of income, be it labour or land, is merely to confine the tax to its own stated objects, viz. to income proper; but to exempt or lower the rate on this income proper, merely in consideration of the personal status of its owner, is to travel into quite a different region—it may be into the region of national charity, or into that of some other principle, but assuredly far away from that of equality in taxation. It may be added that such exemptions, even when admitted, need a common measure of value for their rational application. There are small incomes and small incomes—incomes that are pure interest-values, incomes that are pure drafts on capital, and incomes that are mixtures of interest-value and draft on capital; and the equal exemption of these kinds, as in the present income-tax, is as unequal as would be their equal taxation. As before said, the interest-value measure itself would exempt all small labour-incomes to the extent of their necessities without further special rule.

BEARINGS OF COMMON MEASURE OF VALUE ON GENERAL TAXATION AND NATIONAL INCOME.

11. *Common measure of value necessary to the adjustment of general taxation: fallacies from its absence.*—"Your Committee also feel that it would be unjust to make any alteration in the present incidence of the income-tax, without at the same time taking into consideration the pressure of other taxation upon the various interests of the country, some of it imposed by recent legislation, and in one case especially, that of the succession-duty, to some extent by way of compensation." This, written in 1861, is the last sentence of the Report of the Select Committee appointed in that year on the equalization of the Income-tax; and perhaps no paragraph could be quoted as a stronger argument for the necessity of determining a common measure of value. It may, indeed, be thought by some that for the purpose of internally equalizing a tax over its own area, be that area sugar, coffee, or incomes, a preliminary inquiry into the pressure of taxation in general is somewhat of a work of supererogation; and it may not be mathematically obvious to others what possible sort of compensation can exist between the inequalities of a tax, or a set of taxes, that are almost stationary, and those of one that changes with every national emergency—that in twenty years has actually compassed the extremes of sixteenpence and twopence in the pound, with every variety of intermediate oscillation But assuming it to be advisable for the purpose in question, as it must doubtless be always generally useful, to know the comparative pressure of taxation as a whole upon the interests of the country, it is clear that such a knowledge implies their valuation through a common measure, and is, indeed, as impossible without it as would be the knowledge of the weights of different things without weighing them by a true balance. Eminent statists have, indeed, attacked this problem, using income itself as the means of the comparison, though oftentimes without a sufficient preliminary examination of the accuracy of their instrument. Comparing the statistics of different classes of income, as collected from the government returns and from inquiries specially made, with the statistics of the corresponding classes of taxation, they have sometimes concluded that general taxation is, as a whole, tolerably equal. The truth of this conclusion evidently depends upon the uniformity of the standard employed. As, however, this uniformity has no existence (the government returns alone presenting at least five or six different modes of estimate), the argument can prove nothing as regards general equality, except its absence; but does prove that taxation

in general, regarded as a larger income-tax, is equally in want of a common measure with the income-tax proper. So far from the measurement of the income-tax proper being dependent on the measurement of general taxation, the measure that underlies them both is one and the same, and, indeed, the true view of an income-tax is that it should be a perfectly just and equal tax in itself, rather than an imperfect tax compensating the imperfections of other taxes.

Common measure of value necessary for finding national income and wealth: fallacies from its absence.—The evil consequences of a want of a common measure of value, seen in the *comparison* of incomes for purposes of taxation, is also seen when they are added together for the exhibition of the amount of national income and wealth. To find this national income, the government returns of the income-tax have been taken, and to this miscellaneous aggregate the exempted incomes of the country, including manual-labour wages, have been added, as if all were of one equal and uniform denomination. Much of such income, however, as has been repeatedly pointed out, is only the consumption of capital. Within the period of a generation, say thirty years, all the value of human labour, *plus* the cost of maintaining it, passes into the category of labour-income. Within longer but varying periods the value of all houses, *plus* the cost of repairing them, passes into the category of house-income. Within still more varying periods all the mining wealth of the country must pass into the category of mining-income and disappear; and all capital of terminable annuities passes into terminable income. By some writers this medley of so-called income (but no more income than the payments for exports are income, or drafts on bankers are income) has ever been capitalized at one (and that an extreme) rate, to get the national wealth, the result of the whole process being an exaggerated and practically mischievous estimate of national income, of national wealth, and of the nation's capacity to bear taxation. Probably no better example than this could be given of the necessity of a common measure of value. Common measures (common units) are the souls of statistics, as, indeed, they are of knowledge generally. Without them statistics are a mere incoherent mass of facts, usurping the semblance and function of exact science. A common measure of income, discovering the amount of the element common to rent, wages, profits, and interest, determines the true increment of wealth considered in its widest sense, and expresses both the extent and the ratio of economic progress. This common measure may be briefly described as *interest-value*: it is an essential, if not the fundamental, basis of taxation.

Report of the Committee, consisting of Professor CLERK MAXWELL, Professor J. D. EVERETT, *and* Dr. A. SCHUSTER, *for testing experimentally Ohm's Law.*

THE statement of Ohm's law is that, for a conductor in a given state, the electromotive force is proportional to the current produced.

The quotient of the numerical value of the electromotive force divided by the numerical value of the current is defined as the resistance of the conductor; and Ohm's law asserts that the resistance, as thus defined, does not vary with the strength of the current.

The difficulty of testing this law arises from the fact that the current generates heat and alters the temperature of the conductor, so that it is extremely difficult to ensure that the conductor is at the same temperature when currents of different strengths are passed through it.

Since the resistance of a conductor is the same in whichever direction the current passes through it, the resistance, if it is not constant, must depend upon even powers of the intensity of the current through each element of the conductor. Hence if we can cause a current to pass in succession through two conductors of different sections, the deviations from Ohm's law will be greater in the conductor of smaller section, and if the resistances of the conductors are equal for small currents, they will be no longer equal for large currents.

The first method which occurred to the Committee was to prepare a set of five resistance-coils of such a kind that their resistance could be very accurately measured. Mr. Hockin, who has had great experience in measuring resistance, suggested 30 ohms as a convenient magnitude of the resistance to be measured. The five coils and two others to complete the bridge were therefore constructed, each of 30 ohms, by Messrs. Warden, Muirhead, and Clark, and it was found that a difference of one in four millions in the ratio of the resistance of two such coils could be detected.

According to Ohm's law, the resistance of a system consisting of four equal resistance-coils joined in two series of two should be equal to that of any one of the coils. The current in the single coil is, however, of double the intensity of that in any one of the four coils Hence if Ohm's law is not true, and if the five coils when compared in pairs with the same current are found to have equal resistances, the resistance of the four coils combined would no longer be equal to that of a single coil.

A system of mercury-cups was arranged so that when the system of five coils was placed with its electrodes in the cups, any one of the coils might be compared with the other four combined two and two. After this comparison had been made, the system of five coils was moved forward a fifth of a revolution, so as to compare the second coil with a combination of the other four, and so on.

The experiments were conducted in the Cavendish Laboratory by Mr. G. Chrystal, B.A., Fellow of Corpus Christi College, who has prepared a report on the experiments and their results.

A very small apparent deviation from Ohm's law was observed, but as this result was not confirmed by the much more searching method of experiment afterwards adopted, it must be regarded as the result of some irregularity in the conducting-power of the connexions.

The defect of this method of experiment is that it is impossible to pass a current of great intensity through a conductor without heating it so rapidly that there is no time to make an observation before its resistance has been considerably increased by the rise of temperature.

A second method was therefore adopted, in which the resistances were compared by means of strong and weak currents, which were passed alternately through the wires many times in a second. The resistances to be compared were those of a very fine and short wire enclosed in a glass tube, and a long thick wire of nearly the same resistance. When the same current was passed through both wires, its intensity was many times greater in the thin wire than in the thick wire, so that the deviation, if any, from Ohm's law would be much greater in the thin wire than in the thick one.

Hence, if these two wires are combined with two equal large resistances in

Wheatstone's bridge, the condition of equilibrium for the galvanometer will be different for weak currents and for strong ones. But since a strong current heats the fine wire much more than the thick wire, the law of Ohm could not be tested by any ordinary observation, first with a weak current and then with a strong one, for before the galvanometer could give an indication the thin wire would be heated to an unknown extent.

In the experiment, therefore, the weak and the strong current were made to alternate 30 and sometimes 60 times in a second, so that the temperature of the wire could not sensibly alter during the interval between one current and the next.

If the galvanometer was observed to be in equilibrium, then, if Ohm's law is true, this must be because no current passes through the galvanometer, derived either from the strong current or the weak one. But if Ohm's law is not true, the apparent equilibrium of the galvanometer-needle must arise from a succession of alternate currents through its coil, these being in one direction when the strong current is flowing, and in the opposite direction when the weak current is flowing.

To ascertain whether this is the case, we have only to reverse the direction of the weak current. This will cause the alternate currents through the galvanometer-coil to flow both in the same direction, and the galvanometer will be deflected if Ohm's law is not true.

Mr. Chrystal has drawn up a report of this second experiment, giving an account of the mode in which the various difficulties were surmounted. Currents were employed which were sometimes so powerful as to heat the fine wire to redness, but though the difficulty of obtaining a steady action of the apparatus was much greater with these intense currents, no evidence of a deviation from Ohm's law was obtained, for in every experiment in which the action was steady, the reversal of the weaker current gave no result.

The methods of estimating the absolute values of the currents are described in the Report.

A third form of experiment, in which an induction-coil was employed, is also described; but though this experiment led to some very interesting results, the second experiment gives the most searching test of the accuracy of Ohm's law. Mr. Chrystal has put his result in the following form.

If a conductor of iron, platinum, or German silver of one square centimetre in section has a resistance of one ohm for infinitely small currents, its resistance when acted on by an electromotive force of one volt (provided its temperature is kept the same) is not altered by so much as $\frac{1}{10^{12}}$ part.

It is seldom, if ever, that so searching a test has been applied to a law which was originally established by experiment, and which must still be considered a purely empirical law, as it has not hitherto been deduced from the fundamental principles of dynamics. But the mode in which it has borne this test not only warrants our entire reliance on its accuracy within the limit of ordinary experimental work, but encourages us to believe that the simplicity of an empirical law may be an argument for its exactness, even when we are not able to show that the law is a consequence of elementary dynamical principles.

First Experiment. Christmas 1875. *By* G. CHRYSTAL, *Cavendish Laboratory, Cambridge. Communicated by* J. CLERK MAXWELL.

If the electromotive force between two points of a uniform linear conductor measured in appropriate units by means of an electrometer be E, and the quantity of electricity that passes through any section of the conductor in unit time, measured either by a galvanometer or by a voltameter, be C, then, according to Ohm's law [*], $\frac{E}{C}$ is directly proportional to the length of the conductor, and inversely proportional to the area of its section.

The coefficient of proportionality for a *definite* [†] substance depends merely on the temperature of the substance; for unit length and unit section of a given substance the value of the ratio $\frac{E}{C}$ for a given temperature is called the specific resistance of the substance for that temperature, and is one of the most important of its physical constants.

This law has been *directly* verified by its discoverer, and by Becquerel, Davy, Fechner, Kohlrausch, and others, and *indirectly* it has been verified for a great variety of substances with a degree of accuracy approached in few physical measurements.

Lately, in discussing some experiments of his own, Dr. Schuster has raised the question whether after all Ohm's law is only an approximation, the limit of whose accuracy lies within the region of experiment We might suppose that the ratio $\frac{E}{C}$ [‡] was some function of C^2, say

$$\frac{E}{C}=R-SC^2,$$

where R is a constant very nearly equal to what has hitherto been called the specific resistance, and S is a small constant which, according to Dr. Schuster's suggestion, would be positive It is clear that $\frac{E}{C}$ can only be an *even* function of C, unless we admit *unilateral* conductivity, for which there is no experimental evidence in a purely metallic circuit

A Committee of the British Association, appointed to consider the subject, were of opinion that it was of importance to attempt a further experimental verification of Ohm's law.

At the suggestion of Professor Maxwell, the experimental details of two methods of verification proposed by him were undertaken by the writer of this Report. Of the two experiments representing these methods the second is by far the most conclusive. It not only avoids the difficulty of eliminating temperature effects, which to a certain extent interfere with the first experiment, but it pushes the verification of Ohm's law very near the natural limit of all such verifications, viz. the limit of the solid continuity of the conductor. It has thus been rendered probable that experiment cannot detect any deviation from Ohm's law, either in the direction indicated by Dr. Schuster, or in the opposite direction as suggested by Weber, even in wires that have been brought by the electric current to a temperature beyond red heat.

A third experiment was also tried by the writer of this Report; its result agreed with the others, but, owing to certain peculiarities, it is less conclusive than they are. It led, however, to interesting results of another kind, which seem to show, among other things, that conclusions respecting the accuracy of Ohm's law cannot safely be drawn from experiments of the nature of those made by Dr. Schuster.

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[*] The current is supposed to be *steady*

[†] By *definite* is meant in a given physical condition, except as regards E M F. and flow of E, and temperature. The last is excepted because we are brought face to face with possible temperature variations in the first experiment

[‡] We suppose the conductor to be of unit length and unit section. It is of course the specific resistance which is in question; and this, if variable, will depend on the current per unit of section.

First Experiment.

Suppose that we had five resistance-coils, which, when compared with each other by means of the same current, were equal, say each $=R$. That is to say, if any two of the resistance-coils were inserted in the branches A B and B D of a Wheatstone's bridge, the other two arms, A C and C D, being two other equal resistances, then the galvanometer G inserted between B and C would indicate no current.

Fig. 1

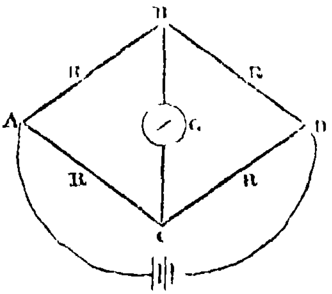
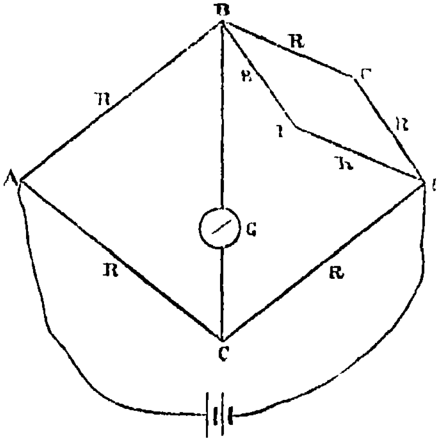


Fig 2.



Suppose now that we replace the coil R in B D by four of the equal coils arranged in multiple arc, as in fig. 2. Then, if Ohm's law be true (*i. e.* if resistance be independent of current), if ρ be the resistance between B and D,

$$\frac{1}{\rho}=\frac{1}{2R}+\frac{1}{2R}=\frac{1}{R},$$

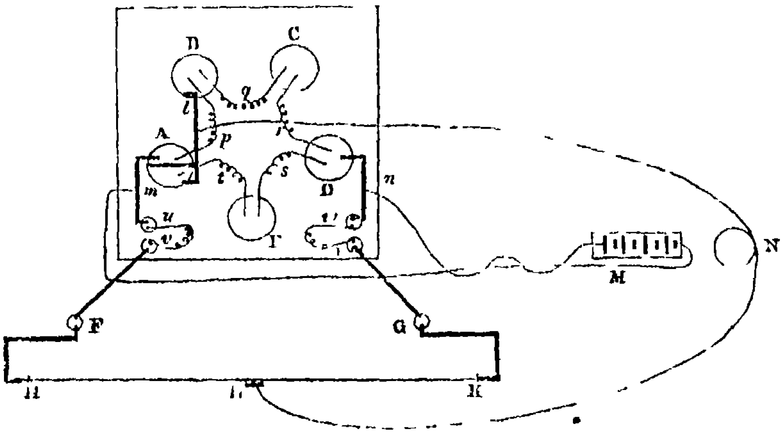
i.e. $\rho=R$, and there will still be no deflection in the galvanometer. But if Ohm's law be not true, and the resistance be a function of the current, then, since the current through A B is nearly the same as in the first experiment, while that through B E D and B F D is half, the resistances in B E, E D, B F, F D will be no longer equal to R, but either greater or less, and the galvanometer will be deflected.

Under the direction of Professor Maxwell, part of the funds at the disposal of the Committee were devoted to providing two sets of coils specially adapted for the above experiment. One set consisted of five coils of silk-covered German silver wire (diameter ·6 millim.), each of resistance as nearly as possible equal to 30 B.A. units. These were all wound together in the usual way round one bobbin; the terminals consisted of ten pieces of stout copper wire, insulated from each other by a ring-shaped piece of ebonite, through which all of them passed. These stout wires were bent over, and cut as nearly as possible of the same length, so that their amalgamated ends might go in pairs into mercury-cups. The wire and bobbin were enclosed between two coaxial cylinders of sheet brass, which were fastened to the ebonite piece above, and connected by a ring of sheet brass below. The whole had a rough resemblance to a large spider The other set consisted of two coils made of the same wire, and having each as nearly as possible the same resistance They were arranged in the same way, except that the terminals of the same coil were adjacent.

As the adjustment of the coils was necessarily not perfect, the experiment could not be tried exactly as described in the above scheme. I decided, therefore, to operate as follows —First, to compare each coil of the five with the coil next in order; the differences between any two coils could then be found in terms of an arbitrary unit (the resistance of a tenth of a millimetre of the platinum-iridium bridge wire at the temperature of the room during the experiment); second, to compare each coil with the four others arranged in multiple arc, as before described The results thus obtained were compared, as will be described further on.

To facilitate these comparisons, the following arrangement of mercury-cup connexions was made for me by Mr Garnett, of St John's College, the Demonstrator at the Cavendish Laboratory :—

Fig. 3.



To a massive board are glued five large mercury-cups, made of boxwood, with a piece of amalgamated sheet copper at the bottom. Into these go the ten terminals of the five coils, so that there would be metallic connexion round all the five coils in series were it not that the cup A is divided by a piece of vulcanite, which insulates the two terminals in that cup. *l* is a stout copper bow connecting B and the lower division of A; to this bow is soldered one of the galvanometer terminals. Into the cups *u* and *v* dip the two terminals of one of the two coils. *m* is a stout bow of copper connecting the upper half of A with *u*. Another bow goes from *v* to F, one end of the bridge, which is the instrument used by the British-Association Committee of 1863, and will be found described at p. 353 of the Report (1864) of the Committee on Electrical Standards. To m is soldered one of the battery terminals. The connexions on the right are similar to those on the left, and may be understood from the diagram. The other galvanometer terminal goes to the contact-block L. The battery used consisted of twelve Leclanché's cells, the whole internal resistance of which was about 13 B.A. units, its E.M.F. being about 16 times that of a Daniell. The whole resistance of the bridge from F to G was about ·075. The galvanometer is an instrument made by Elliott Brothers, belonging to the British Association; its resistance is about half a B.A. unit.

Good contact between the feet of the copper terminals of the quintuple coil and the bottom of the mercury-cups was secured by placing a weight on the top of the coil; the spring in the terminals was then sufficient to ensure contact everywhere.

In the arrangement figured in the diagram the coil p is balanced against a multiple arc, containing q and r in one branch, and s and t in the other. To compare one single coil with the next single coil, l is removed, and one end of the galvanometer wire connected instead with the cup E, while m is made to connect the lower instead of the upper half of A with u; with this arrangement the coil t is balanced against the coil s.

The coils in the quintuple coil are numbered 1, 2, 3, 4, 5; and in experiments with multiple arc the coil between A and B is referred to as the "single coil;" in experiments with single coils those between D and E and E and A are called right coil (R.C.) and left coil (L.C.); the coils between w and x and u and v are called right and left middle coils (R.M.C. and L.M.C.), and are numbered 1 and 2. The bridge is read from left to right.

Some preliminary experiments were made with the apparatus, which showed that the coils had been very well adjusted by the makers, Messrs. Warden, Muirhead, and Clark. It was found that with the arrangement described (the best at our command in the Cavendish Laboratory), the bridge could be read to a quarter, if not to an eighth of a millimetre. A small correction was found necessary for the magnetic field, due to the current in the bridge connexions; this was allowed for by adjusting a loop of the battery-wire till the galvanometer showed no effect when the battery was turned on. Thermoelectric currents in the galvanometer circuit, owing to heating from the hand at the contact-block, were avoided almost entirely by using two pieces of wood, which were interposed between the fingers and the block, and were continually changed so as not to get hot.

The order of experiment was generally as follows:—The weight was adjusted on the quintuple coil, the battery was thrown in for a moment by means of a treadle which closed the battery circuit; if there was no direct effect on the galvanometer, the battery was thrown out, and contact made at the block; the spot of light on the scale was watched through a reading-telescope, and if it was at rest* the battery was thrown in: the deviation indicated which way the block had to be moved to get a balance. Two or three trials in general sufficed to get the balance. The bridge was then read; the middle coils were then reversed, the balance found, and the bridge read again. The difference of the readings gives the difference of the resistances of the middle coils, as may easily be shown (see 'Journal of Society of Telegraph Engineers,' Oct. 1872). The middle coils being replaced as before, the quintuple coil was moved round one step, and the same process repeated.

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* On the avoidance of small thermoelectric effects, see below in the discussion of the second experiment.

Formula of Reduction.

Let the right-hand middle coil (No. 1) be taken to be 30 ohms, the bridge-wire being ·075 of the same units. Let r denote the resistance of this coil, the unit being the resistance of a tenth of a millimetre of the bridge-wire, therefore

$$r = \frac{30 \times 10000}{\cdot 075} = 4000000.$$

Let the resistances of 1, 2, 3, 4, 5 of the quintuple coil, measured in the same units, be $r+\alpha$, $r+\beta$, $r+\gamma$, $r+\delta$, $r+\epsilon$.

Hence, comparing middle coil 1 with 2, 1 being on the right,

$$\frac{r+\alpha}{r+\beta} = \frac{r+b+\mathrm{D}+x}{r+10000+a-x}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where $r+\mathrm{D}$ = resistance of middle coil 2, x the bridge-reading, a and b the resistances of the connexions at its two ends. This gives

$$\alpha-\beta = \{\mathrm{D}-a-b+2(x-5000)\}\left\{1-\frac{10000-x}{r}\right\}, \quad . \quad . \quad (2)$$

all other terms being negligible.

Now the greatest possible value of $10000-x$ is 6000, since the readings never went below 4000, and $\mathrm{D}+2(x-5000)$ was never greater than 400. Hence the term involving $\frac{1000-x}{r}$ is less than

$$\frac{400 \times 6000}{4000000} = \frac{6}{10},$$

and is therefore negligible, since we do not read beyond tenths of a millimetre. Hence we may use the formula

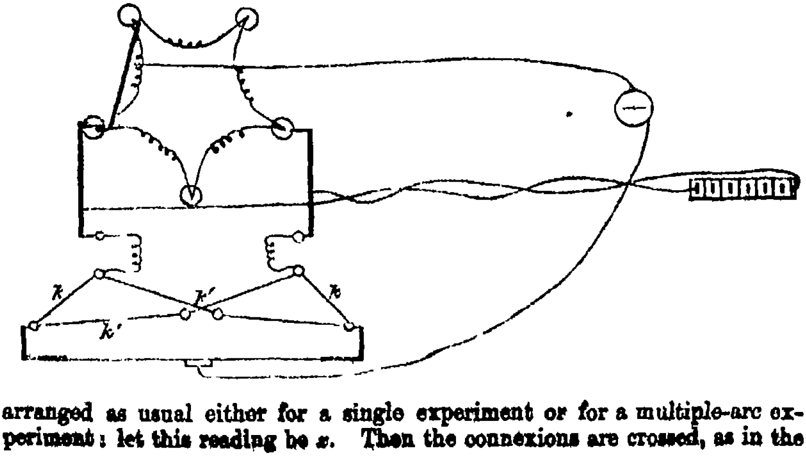
$$\alpha-\beta = \mathrm{D}-\overline{a-b}+2(x-5000). \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Similarly, in comparing one coil against four, we get the formula

$$\alpha-\tfrac{1}{4}(\beta+\gamma+\delta+\epsilon) = \mathrm{D}-\overline{a-b}+2(x-5000). \quad . \quad . \quad (4)$$

To find $\overline{a-b}$, the "bridge correction," a reading is taken with the coils arranged as usual either for a single experiment or for a multiple-arc experiment; let this reading be x. Then the connexions are crossed, as in the

Fig. 4.



figure, by introducing two new pieces of copper and two more mercury-cups, the arrangement independently of the bridge being very nearly symmetrical. let the reading now be x'.

Assuming that the resistances of the movable cups and bows at the two ends are equal, $=k$ in one case, $=k'$ in the other, then

$$\frac{P+k+a+l-x}{Q+k+b+a}=\frac{A}{B}'$$

$$\frac{P+k+a+l-x}{P+Q+2k+a+b+l}=\frac{A}{A+B}$$

Similarly,

$$\frac{P+k+b+x'}{P+Q+2k+a+b+l}=\frac{A}{A+B};$$

$$\therefore\left\{1+\frac{k+a+l-x}{P}\right\}\left\{1-\frac{2k+a+b}{P+Q+l}\right\}$$

$$=\left\{1+\frac{k'+b+x}{P}\right\}\left\{1-\frac{2k'+a+b}{P+Q+l}\right\},$$

$$\therefore 1+\frac{k+a+l-x}{P}-\frac{k+\frac{1}{2}(a+b)}{P}$$

$$=1+\frac{k'+b+x'}{P}-\frac{k'+\frac{1}{2}(a+b)}{P},$$

$$\therefore a-b=x+x'-10000.$$

A variety of experiments were made with the coils arranged sometimes in one way, sometimes in the other, and closely agreeing values of $a-b$ were found varying from 52 to 58.

Correction for want of Symmetry.

Referring back to fig. 4, we see that in the arrangement for multiple-arc experiments the connexions are not quite symmetrical. The copper bows were all nearly of the same length and thickness: let the resistance of one of them be $2b$. Let also the average resistance of a mercury-cup be $2r$. Then we get for the addition to $\frac{1}{4}(\beta+\gamma+\delta+\epsilon)$,

$$\tfrac{1}{4}(2b+10r)+b+r,$$

for the addition to a $2b+4r$. Hence $a-\frac{1}{4}(\beta+\gamma+\delta+\epsilon)$ is too great owing to the connexions by $\frac{b}{2}+\frac{r}{2}$.

Various experiments were made to find the value of $b+r$, and all gave very nearly the same result The following is a specimen:—A copper bow very slightly longer than those in the connexions was inserted by means of an additional mercury-cup, first on the right then on the left of the bridge, the readings were 5032 and 4982, the difference being 50;

$$\therefore 2(b+r)=50,$$

$$\therefore \frac{b}{2}+\frac{r}{2}=12.$$

The correction was actually taken to be 10.

Limits of Temperature Effects.

The coils were arranged for a multiple-arc experiment; the balance was taken at 3·25; the battery was then thrown in and kept in for about a quarter of an hour with the following results:—

h m	x
3 25	5007
3 35	5020
3 42	5022

The reading therefore increased by 15, the greater part of increase taking place in the first 10 minutes. Another series of experiments were made with single coils against single, as follows:—

Time of Obs.	R M C	R C	L C	x	D	
	1	3	2	4914		These experiments were done as quickly as possible, the balance already approximately known was found by three or four instantaneous contacts, so that the coils were as little heated as possible.
	2			5137	223	
	2	2	1	5226		
	1			5008	218	
The battery was thrown in at 12 36 and kept in, the coils being as in last experiment.						
At 12 36	1	2	1	5008	218	The idea was to get 2 heated and then compare it again with 3 which had been very little if at all heated.
12 41 to 12 44	1			5013		
	2			5224	211	
12 56 to 1 00	1			5018		
	2			5223	205	
1 3	1	3	2	4929		
	2			5138	209	
1 8	1	5	4	5036	209	Two fresh coils were taken, the middle coils being as before at difference 209.
1 25				5036		
1 30	2			5234	198	
Crossed connexions				4818		Bridge correction 52

Reducing these experiments by the formula given above we get

D	τ	$\frac{D-52}{2(\tau-5000)}$		Time
223	4914	− 1	$\beta-\gamma$	12 30
218	5008	+182	$\alpha-\beta$	12 36
211	5013	+185		12 41
205	5018	+180		12 56
209	4929	+ 15	$\beta-\gamma$	1 3
209	5036	+229	$\iota-\epsilon$	1 8
198	5036	+218	$\delta-\epsilon$	1 30

Several important inferences may be drawn from these experiments.

1. The difference of resistance between the middle coils decreases as the temperature increases, and that so regularly, that the value of D may be used as a sort of thermometer, indicating how nearly these coils are kept at the same temperature during any series of experiments. This fact shows the propriety of using the appropriate value of D for each case in our reducing formula instead of the average value.
2. The coils 4 and 5 possess the same property, though in a less degree.
3. The coils 1 and 2 possess this property to a very slight extent.
4. The greatest effect that could be produced in a reasonable time on the

difference between 2 and 3, by heating 2 and comparing it with 3 scarcely heated, if at all, was 16

The above peculiarities suggested to me to make a set of experiments on the plan of keeping the current going as much as possible. It was hoped that thus a certain limiting state, as regards temperature, would be arrived at, which from the construction of the coils would in a great measure be independent of small variations of temperature in the experimenting-room *.

This method of proceeding would not introduce any error in the comparison of single coil with single, and the error introduced into multiple-arc experiments would be regular and could be allowed for The last of the sets of experiments given below was conducted on this plan with satisfactory results

Tabular Scheme of best Experiments.

Single Coil with Single					Multiple Arc				
R.M.C	R C	L C	x	D	R M C.	Single C	x	D	
2	2	1	5234						Starting fresh and working quickly
1	,,	,,	5022	212					
1	3	2	4921						
2	,,	,,	5135	214					
2	4	3	5074						
1	,,	,,	4862	212					
1	5	4	5046						
2	,,	,,	5255	209					
2	1	5	4973						
1	,,	,,	4760	213					
2	2	1	5228		1	1	5000		The multiple-arc experiments were started fresh, battery reversed, but no difference found. The single-coil experiments followed some little time after, some experiments with cups and bows having been made in the interval
1	,,	,,	5011	217	2	,,	5223	223	
1	1	5	4768		2	5	5035		
2	,,	,,	4982	214	1	,,	4810	225	
2	5	4	5250		1	4	4960		
1	,,	,,	5039	211	2	,,	5180	220	
1	4	3	4861		2	3	5106		
2	,,	,,	5078	217	1	,,	4891	215	
2	3	2	5140		1	2	4892		
1	,,	,,	4925	215	2	,,	5110	218	
2	2	1	5228		1	1	5024		These experiments were worked slowly, the current being kept on as much as possible The single-coil experiments came first The last line gives a control experiment The correction for magnetic field was forgotten in the multiple-arc experiments, and in consequence 4 must be added to x throughout in the second set
1	,,	,,	5028	200	2	,,	5227	203	
1	1	5	4771		2	5	5032		
2	,,	,,	4972	201	1	,,	4825	207	
2	5	4	5238		1	4	4963		
1	,,	,,	5038	200	2	,,	5170	207	
1	4	3	4861		2	3	5089		
2	,,	,,	5067	206	1	,,	4884	205	
2	3	2	5143		1	2	4905		
1	,,	,,	4935	208	2	,,	5108	208	
1	2	1	5024		2	1	5228		

---

* No special means of keeping the double and quintuple coils at a constant temperature was resorted to. The object was not to find the resistances of the coils at any definite temperature, but to compare them under the *same* circumstances as regards temperature. It was therefore thought that any attempt to surround the coils with water, &c would introduce greater errors than would arise from small variations of temperature in the room during the experiment.

Reduction and Comparison of the foregoing Experiments.

	D	x	$D-58$ $+$ $2(x-5000)$		D	x	$D-58-10$ $+2(x-5000)$	Calc	Diff Obs Calc.	
1	212	5022	+198	198						The third column gives the values of $\alpha-\beta$, $\beta-\gamma$, $\gamma-\delta$, $\delta-\epsilon$, $\epsilon-\alpha$, the fourth the values of $\alpha-\beta$, $\alpha-\gamma$, $\alpha-\delta$, $\alpha-\epsilon$, calculated from these
	214	4921	− 2	196						
	212	4862	−112	84						
	209	5046	+243	327						
	213	4760	−325							
			+ 2							
2	217	5011	+181	181	223	5000	+165	+184	− 29	The seventh and eighth columns give the values of $\alpha-\frac{1}{4}(\beta+\gamma+\delta+\epsilon)$, $\beta-\frac{1}{4}(\alpha+\gamma+\delta+\epsilon)$, &c observed in multiple-arc experiments, and calculated from the values of $\alpha-\beta$, $\alpha-\gamma$, &c before found
	215	4925	+ 7	188	218	4892	− 66	− 42	− 24	
	217	4861	−119	69	215	4891	− 69	− 51	− 18	
	211	5039	+231	300	220	4960	+ 72	+ 98	− 26	
	214	4768	−308		225	4810	−223	−191	− 32	
			− 8				−131		−129	
3	200	5028	+204	204	203	5028	+197	+217	− 20	The last column gives the excess of the observed over the calculated values of $\alpha-\frac{1}{4}(\beta+\gamma+\delta+\epsilon)$, &c
	208	4935	+ 26	230	203	4909	− 41	− 38	− 3	
	206	4861	−124	106	205	4888	− 81	− 70	− 11	
	200	5038	+224	330	207	4967	+ 79	+ 85	− 6	
	201	4771	−309		209	4829	−197	−195	− 2	
			+ 21				− 43		− 42	

N B —In the last set of experiments 52 was used instead of 58 as the bridge correction.

The first thing to remark is the smallness of the sums of $\alpha-\beta$, $\beta-\gamma$, $\gamma-\delta$, $\delta-\epsilon$, $\epsilon-\alpha$, as found from single-coil experiments, the sum is theoretically zero, and the largest deviation is about 20, which divided by 5 gives only 4 for the average error of a determination. Here no error from want of symmetry comes in, and errors from irregular temperature effects very nearly balance each other.

In the next place, taking the multiple-arc experiments of series No 2, we see that there is a deviation of the observed from the calculated values of $\alpha-\frac{1}{4}(\beta+\gamma+\delta+\epsilon)$ which averages 26, and here, from the way the experiments were conducted, the temperature disturbances are probably very small. Again, take the multiple-arc experiments of series No. 3. Here, from the manner of experimenting, the temperature effects *will* appear. We found that the greatest effect we could produce on one of the coils in a reasonable time was about 15, supposing that the whole of this was manifested in the single coil, we should get a quarter as much in each of the coils in the multiple arc (because the current is halved), that is, we have $\frac{2}{3}$ of 15 altogether in $\alpha-\frac{1}{4}(\beta+\gamma+\delta+\epsilon)$; this necessitates a correction of about 10 to be subtracted from the observed values. This is clearly the maximum correction, for after the first experiment we turn into the multiple-arc coils that have already been fully heated. Supposing, however, that we apply the full correction in each case, we get for the average difference —18.

This deviation is in the direction indicated by Schuster's experiments, but it is excessively small: suppose we call it -20 for convenience of calculation; this corresponds to the fraction $\frac{20}{4,000,000}=\frac{1}{200,000}$ of 30 ohms.

But the whole deviation is probably introduced by some slight defect in the apparatus, and part at least can be accounted for; for it occurred to me, in looking over the results quoted above, that a defect in the insulation at the divided cup would partly account for such a deviation. Suppose that the divided cup offered a very large, but not infinite, resistance f to the passage of the current, then the single coil in multiple-arc experiments would be replaced by a multiple arc of resistance R^1, where $\frac{1}{R^1}=\frac{1}{30}+\frac{1}{f}$.

Hence

$$R^1=30-\frac{30^2}{f}$$

Now let us find what f must be to give a decrease of 20 in our observed value of $\alpha-\frac{1}{4}(\beta+\gamma+\delta+\epsilon)$.

$$\frac{30^2}{f}=\frac{20}{10000}\cdot 075$$

$$f=6,000,000$$

that is, $f=6$ megohms. Curiously enough, when I proceeded to measure the insulation resistance of the divided cup it came out very nearly 6 megohms, but the insulation resistance between any two of the remaining cups was found to be about 12 megohms, which reduces the correction somewhat. The complete solution of the problem would be complicated, but we may approximate by considering each of the coils in the multiple arc replaced by a multiple arc whose arms are 30 ohms and 12 meghoms respectively; this requires that β, γ, δ, ϵ should each be reduced by 10. Hence the whole reduction in $\alpha-\frac{1}{4}(\beta+\gamma+\delta+\epsilon)$ would be on this supposition 10. It would really be somewhat less; however, this would almost bring the deviation between observation and calculation within the limits of experimental error. Any remaining difference is probably due to a defect in some mercury-cup in the multiple arc, for there being more there than on the other side of the balance the chance of a defect is greater.

It ought to be mentioned that the insulation of the quintuple coil was tested, and found in every case to be of a higher order of magnitude than a megohm.

Some time after the series of experiments just described, I dismounted the mercury-cups from the stand, which had meantime been carefully dried on the hot-water pipes in the laboratory. Each cup was remounted with a piece of gutta percha between it and the board; and the divided cup, which was found radically defective, was replaced by two mercury-cups on separate pieces of insulating material. The insulation between every pair of cups was then tested afresh and found in every case of a higher order than a megohm.

The experiments were then repeated with the altered stand. The sensibility of the arrangement was about the same as before, although a less electromotive force was used (10 cells). The results were much the same as before, except that the sum of the values of $\alpha-\frac{1}{4}(\beta+\gamma+\delta+\epsilon)$, &c. was now much smaller, two experiments giving -31 and -34. Dividing this by 5, we get -6 for the average deviation, which is very small. The fact that we still get a result in the same direction shows that this is not an accidental error; but it might very well be accounted for by some of the suppositions mentioned already. It might also arise from over-correction for symmetry.

On the whole, therefore, we cannot conclude that there was any deviation from Ohm's law under the circumstances of this experiment. It is hardly worth while to estimate the value of this experiment quantitatively, as the second experiment now to be described is so far superior in this respect.

SECOND EXPERIMENT.

Introduction, by Prof. MAXWELL.

The service rendered to electrical science by Dr G S Ohm can only be rightly estimated when we compare the language of those writers on electricity who were ignorant of Ohm's law with that of those who have understood and adopted it

By the former, electric currents are said to vary as regards both their "quantity" and their "intensity," two qualities the nature of which was very imperfectly explained by tedious and vague expositions

In the writings of the latter, after the elementary terms "Electromotive Force," "Strength of Current," and "Electric Resistance" have been defined, the whole doctrine of currents becomes distinct and plain.

Ohm's law may be stated thus:—

The electromotive force which must act on a homogeneous conductor in order to maintain a given steady current through it, is numerically equal to the product of the resistance of the conductor into the strength of the current through it If, therefore, we define the resistance of a conductor as the ratio of the numerical value of the electromotive force to the numerical value of the strength of the current, Ohm's law asserts that this ratio is constant—that is, that its value does *not depend on that* of the electromotive force or of the current

The resistance, as thus defined, depends on the nature and form of the conductor, and on its physical condition as regards temperature, strain, &c.; but if Ohm's law is true, it does not depend on the strength of the current.

Ohm's law must, at least at present, be considered a purely empirical one No attempt to deduce it from pure dynamical principles has as yet been successful; indeed Weber's latest theoretical investigations* on this subject have led him to suspect that Ohm's law is not true, but that, as the electromotive force increases without limit, the current increases slower and slower, so that the "resistance," as defined by Ohm's law, would increase with the electromotive force. On the other hand, Schuster † has described experiments which lead him to suspect a deviation from Ohm's law, but in the opposite direction, the resistance being smaller for great currents than for small ones.

Lorentz ‡, of Leyden, has also proposed a theory according to which Ohm's law would cease to be true for rapidly varying currents The rapidity of variation, however, which, as he supposes, would cause a perceptible deviation from Ohm's law, must be comparable with the rate of vibration of light, so that it would be impossible by any experiments other than optical ones to test this theory.

The conduction of electricity through a resisting medium is a process in which part of the energy of an electric current, flowing in a definite direction, is spent in imparting to the molecules of the medium that irregular agitation which we call heat To calculate from any hypothesis as to the molecular constitution of the medium at what rate the energy of a given current would be spent in this way, would require a far more perfect knowledge of the dynamical theory of bodies than we at present possess. It is only by experiment that we can ascertain the laws of processes of which we do not understand the dynamical theory.

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* Pogg Ann 1875 † Report of British Association, 1874.

‡ Over de Terugkaatsing en Breking van het Licht. Leiden, 1875.

We therefore define, as the resistance of a conductor, the ratio of the numerical value of the electromotive force to that of the strength of the current, and we have to determine by experiment the conditions which affect the value of this ratio.

Thus if E denotes the electromotive force acting from one electrode of the conductor to the other, C the strength of the current flowing through the conductor, and R the resistance of the current, we have *by definition*

$$R=\frac{E}{C};$$

and if H is the heat generated in the time t, and if J is the dynamical equivalent of heat, we have by the principle of conservation of energy

$$JH=ECt=RC^2t=\frac{E^2}{R}t$$

The quantity R, which we have defined as the resistance of the conductor, can be determined only by experiment. Its value may therefore, for any thing we know, be affected by each and all of the physical conditions to which the conductor may be subjected.

Thus we know that the resistance is altered by a change of the temperature of the conductor, and also by mechanical strain and by magnetization.

The question which is now before us is whether the current itself is or is not one of the physical conditions which may affect the value of the resistance, and this question we cannot decide except by experiment.

Let us therefore assume that the resistance of a given conductor at a given temperature is a function of the strength of the current Since the resistance of a conductor is the same for the same current in whichever direction the current flows, the expression for the resistance can contain only even powers of the current

Let us suppose, therefore, that the resistance of a conductor of unit length and unit section is

$$r\,(1+sc^2+s'c^4+\&c\,),$$

where r is the resistance corresponding to an infinitely small current, and c is the current through unit of section, and s, s' &c are small coefficients to be determined by experiment The coefficients s, s' &c represent the deviations from Ohm's law. If Ohm's law is accurate, these coefficients are zero; also if e is the electromotive force acting on this conductor,

$$e=rc(1+sc^2+s'c^4+\&c\,).$$

Now let us consider another conductor of the same substance whose length is L and whose section is A; then if E is the electromotive force on this conductor, and e that on unit of length,

$$E=Le.$$

Also if C be the current through the conductor and c that through unit of area,

$$C=Ac.$$

Hence the resistance of this conductor will be

$$R = \frac{E}{C} = \frac{Lr}{A}\left(1 + \frac{sC^2}{A^2} + \frac{s'C^4}{A^4} + \&c\right)$$

Now let us suppose two conductors of the same material but of different dimensions arranged in series and the same current passed through both

$$R_1 = \frac{L_1 r}{A_1}\left(1 + \frac{sC^2}{A_1^2} + \&c\right),$$

$$R_2 = \frac{L_2 r}{A_2}\left(1 + \frac{sC^2}{A_2^2} + \&c.\right),$$

where the suffixes indicate to which conductor the quantities belong. The ratio of the resistances is

$$\frac{R_1}{R_2} = \frac{L_1}{A_1}\frac{A_2}{L_2}\left(1 + sC^2\left(\frac{1}{A_1^2} - \frac{1}{A_2^2}\right) + \&c\right).$$

Hence if Ohm's law is not true, and if, therefore, any of the quantities s, s', &c. have sensible values, the ratio of the resistances will depend on the strength of the current.

Now the ratio of two resistances may be measured with great accuracy by means of Wheatstone's bridge.

We therefore arrange the bridge so that one branch of the current passes first through a very fine wire a few centimetres long, and then through a much longer and thicker wire of about the same resistance. The other branch of the current passes through two resistances, equal to each other, but much greater than the other two, so that very little of the heating-effect of the current is produced in these auxiliary resistances.

The bridge is formed by connecting the electrodes of a galvanometer, one to the junction of the fine wire and the thick one, and the other to a point between the other two resistances.

We have thus a method of testing the ratio of the resistances of the fine wire to that of the thick one, and by passing through the bridge sometimes a feeble current and sometimes a powerful one, we might ascertain if the ratio differed in the two cases.

But this direct method is rendered useless by the fact that the current generates heat, which raises the temperature of both wires, but that of the thin wire most rapidly, and this makes it impossible to compare the effects of strong and weak currents through a conductor at one and the same temperature.

It is also useless to work with weak currents, as the effect depends on the square of the current, and is so small as to have escaped observation in all ordinary experiments.

Again, if we were to use a single very strong current acting for a very short time, we should not be able to observe the galvanometer in a satisfactory manner. In fact it was found in the experiment that currents which lasted for a sixtieth part of a second produced a heating-effect which interfered with the measurements. The experiment was therefore arranged so that a strong current and a weak one were passed through the bridge alternately; and when the bridge was so arranged that the galvanometer was in equilibrium, the direction of the weaker current was reversed. If Ohm's law were not true, the condition of equilibrium for strong currents would be different from that for weaker ones, so that when the weak currents were reversed there would be no longer equilibrium Since, in point of fact, the reversal of the weaker currents did not affect the equilibrium, it follows that the bridge was in equilibrium for the weaker currents as well as for the stronger ones, and therefore the conditions were the same for both, and Ohm's law is true to within the limits of error of the experiment. The mode in which the actual strength of the currents was measured and the limits of error ascertained, are described in the following Report by Mr. Chrystal.

Report on the Second Experiment *By* G CHRYSTAL.

As has been pointed out by Professor Maxwell, the change in the specific resistance of a linear conductor, if there be any such change owing to increase or decrease of the current, will depend on the amount of current that passes through unit of area of its section, so that if C be the whole current passing, r the specific resistance for infinitely small current, l the length, w the section, and h a constant depending on the nature of the conductor, then the resistances of the conductor will be

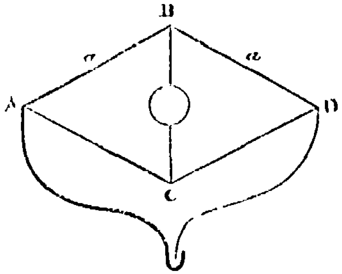
$$\frac{lr}{w}\left(1-h\frac{C^2}{w^2}\right);$$

or if R be the resistance for infinitely small currents, $R\left(1-h\frac{C^2}{w^2}\right)$ *.

It is clear, therefore, that by making up a resistance of very fine wire, say $\frac{1}{500}$ of an inch in diameter, any such effect as that we have been looking for would be greatly multiplied Accordingly the following experiment, the principle of which is due to Professor Maxwell, was undertaken by the writer of this Report.

The figure represents a Wheatstone's bridge, in which the resistances AB and BD are each equal to a (in the actual experiment 30 ohms), AC a resistance made up of a thin wire whose resistance for infinitely small currents is R (this we suppose to be duly corrected for temperature, as will be explained by-and-by), and partly of a length of the thick platinum-iridium wire of the B A. bridge, whose resistance is x CD consists of a resistance composed of thick wire equal to R, and of the rest of the bridge-wire, whose resistance is $l-x$

Fig. 5.



With a current C, w being the section of fine wire, its resistance is $=R(1-\mu C^2)$, where

$$\mu=\frac{h}{w^2}.$$

If $\rho=\frac{2Ra}{R+a}$ be the approximate resistance of the whole bridge (we suppose that there is nearly a balance), B that of the battery circuit, then E being the electromotive force of the battery,

$$C=\frac{\rho}{B+\rho}\frac{E}{2R}=PE.$$

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* The sign of h is chosen according to Schuster's suggestion.

Then Δ denoting the determinant of the system of resistances (see Maxwell's 'Electricity,' vol. i. p. 399), we have, g denoting the current in the galvanometer,

$$g=\frac{aE}{\Delta}\{l-2x+R\mu P^2L^2\} \quad . \qquad (1)$$

From (1) it follows at once that the greater L the further to the right the balance will be, provided μ is >0.

Let us now, instead of keeping up an electromotive force E constantly, make an alternation some hundred times a second between an electromotive force E and an electromotive force yE*; then supposing each to operate for an equal time, the whole current through the galvanometer is given by

$$g=\frac{a}{2\Delta}\{(l-2x)(1+y)E+R\mu P^2E^3(1+y^3)\} \qquad (2)$$

if the electromotive force has in both cases the same direction, and by

$$g=\frac{a}{2\Delta}\{(l-2x)(1-y)E+R\mu P^2E^3(1-y^3)\} \quad . \quad . \quad . \qquad (3)$$

if the directions are opposite.

It appears, therefore, as was obvious without calculation, that the values of x which give a balance are neither the same in the two cases (2) and (3), nor equal to that in the case of either electromotive force acting continuously. In fact the balance is an apparent one if μ be >0, due to the fact that we are in case (2) as much under the balance for the larger electromotive force (*quâ* effect on the galvanometer) as we are over that for the smaller, so that the needle is kicked equally this way and that so rapidly that it remains still. Similar reasoning would show that the balance for case (3) lies most to the right of all. In fact the values of x are:—

Smaller electromotive force alone $x = \frac{1}{2}\{l+R\mu P^2y^2E^2\}$,
Case (2) $x = \frac{1}{2}\{l+R\mu P^2(1-y+y^2)L^2\}$,
Larger electromotive force alone $x = \frac{1}{2}\{l+R\mu P^2E^2\}$,
Case (3) $x = \frac{1}{2}\{l+R\mu P^2(1+y+y^2)L^2\}$,

which are evidently in ascending order if y be <1.

Suppose now we find the balance for case (2) and then reverse our smaller electromotive force; the balance being thus disturbed, there will be a current through the galvanometer, and in order to experiment at the greatest advantage this must be made a maximum.

Substituting the second of the above values of x in formula (3), we get

$$g=\frac{a}{\Delta}R\mu P^2L^3(y-y^2), \quad . \quad . \quad . \quad \quad . \quad . \quad . \qquad (4)$$

which is a maximum as far as y is concerned when $y=\frac{1}{2}$, the value of g being then

$$g=\mu\frac{aRP^2E^3}{4\Delta} \quad . \quad . \quad . \quad \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (5)$$

The advantage of this method of experimenting is that it eliminates to a great extent the temperature effect, which is similar to the effect we are looking for, except that it depends on the time, which the other probably would not do, and it is of course opposite in direction. If we make our alternations quick enough the wire will not cool sensibly during the smaller current, nor heat sensibly during the larger, but will settle down to a mean temperature between that due to the larger and smaller currents.

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* N.B. In what follows y is supposed < 1.

In the above calculation we have supposed the resistance of the fine wire for infinitely small currents to be that corresponding to this mean temperature, which will be constant throughout the experiment provided the electromotive forces do not vary.

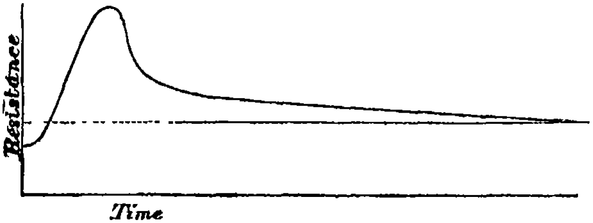
If, however, the alternations are not quick enough to ensure temperature-equilibrium, then the thin wire will be hotter during the passage of the larger current than it is during that of the smaller; and there will be an effect opposite to that we are looking for, a result which appeared in many of the experiments

The experiment proved very difficult in practice, chiefly owing to the difficulty experienced in getting a good alternator, and it was only after a great many total or partial failures that any thing like success was attained. A sketch of the progress of the experiment, with an account of the more important difficulties, and how they were finally avoided or overcome, may be of some interest

In the first place the galvanometer indications in a Wheatstone's bridge, arranged as above described, are somewhat peculiar

Suppose we are somewhere near a balance for some temperature of the thin wire above that of the room, then on turning on the current there is a sharp kick in one direction, say to the right, then a slower but still tolerably quick swing over to the left, and then a gradual subsidence back to zero or thereabouts, which may last for half an hour or longer. If this were due solely to variation in the resistance of the thin wire the curve of time-resistance would be of this nature—

Fig. 6.



It had been found that the thin wire was very sensitive to air-currents, merely blowing towards it from a considerable distance sending the spot off the galvanometer-scale, in fact to get any approach to steadiness the wire had to be enclosed in a box, and latterly it was enclosed in a narrow tube, and that again loosely rolled in a silk pocket-handkerchief, and the whole enclosed in a box It was therefore at first suspected that the peculiarity in question was due to air-currents; but some experiments with the wire in an exhausted tube showed that it was due to some other cause This cause was found in the slow heating of the thick wire against which the thin wire was balanced, and some obvious experiments were made confirming this conclusion*.

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* The behaviour of the galvanometer is therefore explained in this way —The first sharp short kick is due to the fact that before the thin wire is heated its resistance is much smaller

This slow variation of the balance was sometimes avoided by letting the batteries work until it had died away, and sometimes it was allowed for by suitably arranging the order of experiment.

As it was of considerable importance to have a battery which could be relied on for constancy for some time, six large Daniells were charged for the purpose. They were cells intended for a Thomson's battery, but were fitted up for convenience with copper plates 18 inches square, upon which was strewed sulphate of copper, which again was covered with a thin layer of sawdust moistened with zinc sulphate, and on the top of this was placed a heavy grating of zinc. Two piles were made consisting respectively of four and two of these elements, and were used in most of the experiments. The internal resistance of these piles ran to about 4 and 3 ohms respectively. The electromotive force was repeatedly tested during the experiments.

At first a Morse key worked rapidly by the hand was tried for an alternator; this method, though leading to no definite results, seemed to show the possibility of success. Then a rotating alternator driven by hand was tried, but it was found that the results though much better were still very much disturbed by the irregularities of the driving. Next a rotating alternator was made by Mr Garnett and fitted to a Jenkin's governor; this also after repeated trials was given up, the main difficulty being that of getting up sufficient speed without introducing so much resistance as to go beyond the range of the governor. Some of the results got with this arrangement were fairly good, however, and will be given below. In the arrangement adopted in the final experiments the alternation was managed by means of a pair of electric tuning-forks. For the use of these during the Lent term I am indebted to the kindness of Dr Michael Foster.

Final Arrangement.

Fig. 7, p. 56, gives a scheme of the final arrangement. A B is the bridge already mentioned in the Report. E G C is the galvanometer circuit. Between D and E and F and I are inserted two resistances of 30 ohms each. W is the fine wire. H a coil of thick German silver wire of resistance nearly equal to that of the fine wire. K a small resistance-box from which twentieths could be got, the final adjustment being of course made by moving the block C. D is connected with the stem of the tuning-fork P Q, whose prongs are each provided with a dipper, and corresponding to the dippers are two mercury cups whose heights are adjustable. M and N are the piles of four and two Daniells. O is a commutator, by means of which the smaller battery can be thrown in either way, or thrown out altogether as desired. One terminal of the commutator goes to the cup T, the other to F. The other cup, S, is connected with one pole of the larger battery, the other pole of which is connected with F through a key, I, by opening or closing which the battery M may be thrown out or in at pleasure. The rest of the figure represents an auxiliary battery, U, whose circuit goes through another fork, V W, working a break at W, and through the electromagnets of the forks V W and P Q. This latter battery and fork therefore simply drive the fork P Q.

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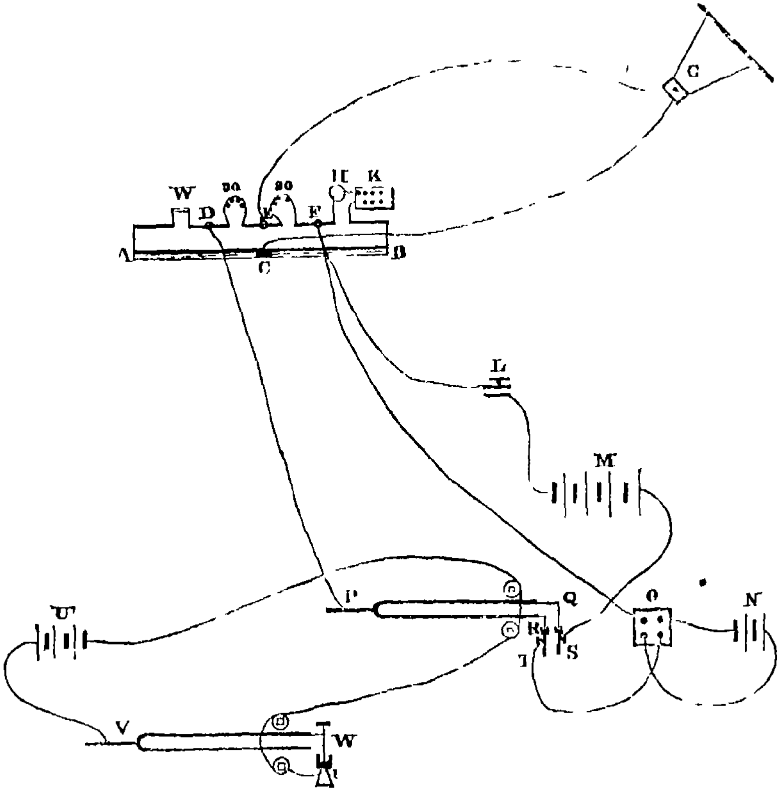
than that corresponding to a balance, the quick swing in the opposite direction is due to the sudden rise of temperature causing a corresponding increase of resistance, the slow return movement is due to the increase of the balancing resistance owing to the gradual development of heat in the thick wire.

Fig. 7.



The action of PQ is obvious. When the prongs approach each other the upper dipper is depressed into the mercury in S, while the lower dipper is raised out of the mercury in T, so that the current of the larger battery passes, and *vice versâ* when the prongs separate; and it is easy enough by throwing a galvanometer in instead of one of the batteries, and then setting the fork going with the other on, to adjust the break in such a way that there is perfect independence between the two currents. This test was in fact actually applied either at the beginning or end of each set of experiments. We have thus alternately sent through the bridge certain definite fractions of the whole current due to the large and small batteries. What fractions these are will depend on the nicety with which the break is adjusted (with perfect adjustment it would be one half of each), and also on the state of the mercury surfaces and of the dippers. As may be imagined, the main difficulty of the experiment lay in getting the dippers to work properly. Several sorts were tried; plain copper amalgamated was found to act fairly well, but broad spade-shaped pieces of platinum-foil answered on the whole best. The surface of the mercury was covered with spirit, which is effectual so far in preventing the spoiling of the surface; but ultimately the cups get clogged with finely divided mercury, and then all regular action is at an end. It was found, however, that with some care the break could be got to work long enough to allow of good results being obtained.

On account of this gradual alteration of the break and for other reasons as well, it was of vital importance to be able during the experiment to obtain some measure of the amount of current that passed as representative of the large and small current respectively; for the experiment would obviously be nugatory if, instead of the smaller current being nearly half the larger, it became, owing to deterioration of contact in the cup S, equal to what ought to be the larger current. To provide for this the experiments were conducted as follows:—The balance was found whether for larger currents alone or smaller alone (acting directly or with the fork going), or for both together, either in the same or in opposite directions; then the block was moved as quickly as possible 6 centims from the position of balance, and the deflection which then appeared was read off; this deflection is approximately proportional to the current. Knowing then the electromotive force of either battery and its internal resistance, one could not only tell whether the currents were passing nearly in the right proportion, but also estimate roughly how much current absolutely passed in each case. In some of the best experiments a more accurate method was adopted.—The point D was put to earth and the point I connected by means of a long insulated wire with one pair of the quadrants of a Thomson's electrometer in the flat of the laboratory below the room where the experiment was carried on; the other pair of quadrants being "put to earth," the deflection observed on the electrometer scale was a direct measure of the electromotive force between D and I—that is, of the quantity denoted above by $\frac{\rho}{B+\rho}E$.

Before giving the quantitative results obtained from the most satisfactory experiments, it may be well to explain the principle on which these have been selected from the others. In all the experiments quoted there was either something remarkable, such as a high battery power, &c., or else the balances were obtained under very favourable circumstances, the spot of light being very steady, and the proportions of current passing, as indicated by the sensibilities* or electrometer measurements, being near the theoretically best amounts. Often where the breaks were not working satisfactorily, by working quickly a qualitative experiment could be made, the behaviour of the galvanometer indicating to an observer practised in the experiment that the proportions of current passing were not far wrong; and often part of an experiment could be made perfectly satisfactorily, and then the apparatus would go out of order. But in all the experiments, whenever the results were at all intelligible (regular), the conclusion pointed to never differed from that given by the best experiments, viz. either the balance for the currents in opposite direction lay more to the left than that for the currents in the same direction, or the two coincided. Of this the observer spared no trouble in assuring himself even in experiments that were quantitatively utterly valueless.

The first set of experiments quoted, which are not of much value quantitatively, may serve to illustrate what has just been said. In this set the time is given because the experiments were made during the slow heating-effect already alluded to. The spot of light was not perfectly steady, though much steadier for the +— balances than for the others; the bridge-reading is given to tenths of a millimetre, though of course in the present case for the + + balances accuracy to less than a millimetre was not attained. The alternator was the rotating piece made by Mr. Garnett, driven by the governor, which, judging by the regularity and smallness of the oscillations of its brake-wheel, went very uniformly during the whole experiment The rate of revolution was about three turns (causing as many alternations) per second. The sensibilities for + + and + – were respectively about 150 and 45 during the experiment, so that the large and small currents would be proportional to about 97 and 52 respectively The fine wire was a small length of German-silver wire $\frac{1}{500}$ in. in diameter, whose resistance was about 7·3 ohms, and the counter-balancing resistance was 7·3 ohms, taken entirely from the small resistance-box. The governor being started, the batteries were set on at 4.6

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* The deflection due to six centimetres deviation from balance is called the sensibility.

Time	Large Battery	Small Battery	Bridge
4.15	+	–	5880
17	+	+	5980
18	+	–	5805
23	+	+	5770
25	+	–	5518
47	+	–	6612
49	+	+	6785
51	+	+	7032
52	+	–	6178
55	+	+	6820
57	+	–	6418
5.00	+	+	6605
5.10	+	–	6308

It will be seen that with some little irregularity the balance on the whole went steadily to the right during some three quarters of an hour. In one point all the observations agree, viz. that the + – balance is more to the left by 1 to 3 centimetres than the + + for the corresponding time. If ΔR be the amount by which the average resistance is less for the smaller than for the larger current, then taking 250 as the difference between the balances, we get easily, from the formulæ given above (our unit of resistance being the resistance of $\frac{1}{10}$ millim. of the bridge-wire, *i. e.* $\frac{875}{10000}$ ohm),

$$\Delta R = \frac{250}{y} = 500 \text{ (taking } y = \tfrac{1}{2}\text{)}.$$

Now the variation in resistance of German silver being about ·044 per cent. per deg. Cent., we get for 1° C on 7·3 ohms a variation of about 430 in our present units Hence the average temperature of the thin wire was something over 1° C less during the smaller than during the larger current. Neither the magnitude of the cooling effect nor the irregularities in the progression of the balance in this experiment is to be wondered at, since we know that air-currents have a very powerful effect in cooling the thin wire; and here the wire was merely enclosed in a box to protect it from air-gusts, but was otherwise unprotected. We ought therefore to expect very little of this effect in most of the following experiments, where the alternations were 20 times as fast, and where the wire was enclosed in a narrow tube protected from temperature variations

In the experiment next quoted, the alternations were made by means of the tuning-forks, and were at the rate of 60 per second. The resistance of the thin wire was very nearly the same, and it was enclosed in a narrow tube. The four Daniells had run down a good deal, being not quite equivalent to three, and the two had varied in proportion The resistance which balanced the wire was, exclusive of the bridge-wire, 7·25 ohms.

Large Battery	Small Battery	Bridge	Sensibility
+	+	5110	
+	−	A little to left	
+	+	1830	
+	−	No difference	
+	+		95
+	−		45
+			70
	+		20

It will be seen that the effect that was so conspicuous in the first experiment scarcely appears here at all It was in fact so small that its appearance might be due to progress of the balance in the interval between the five observations.

In the next experiment the wire had a resistance of about 1·4 ohms, the material was German silver, and the diameter the same as before The resistance against which it was balanced was a German-silver wire of about ·12 centim diameter, wound on a bobbin, the resistance of which was 4·45 ohms. The Daniells had been fresh charged, and were arranged in piles of four and two as usual, the respective internal resistances being about 5 and 3. The small resistance-box was on the left with the thin wire

L B	S B	Box	Bridge	Sensibility
+	+	0·00	2165	165
+	−	0·00	2165	42
Here the dippers were slightly adjusted				
+	−	0·00	2330	53
+	+	0·00	2330	170
+		0·00	4310	105
..	+	0·05	5940	51

The experiment is marked in the laboratory book as very steady It will be remarked that the sensibilities are large and well proportioned, for if we had theoretically perfect adjustment, the sum would have been 156 and the difference 54, as against 170 and 53 The + + balance is of course much more delicate than the + −, but even for the latter (6 centimetres giving, say, 54) we have 8 scale-divisions to a centimetre, so that we may rely on our + − balances to about a millimetre This experiment therefore indicates a coincidence of the two balances within ·0016 per cent.

A good many experiments were tried with higher electromotive forces; but though qualitative results of some interest were got, sufficient steadiness could not be obtained to make the results of use quantitatively. In most of these the thin wire was over a red heat, in fact in many of them the experiment ended with the melting of the wire. In general there appeared to be a good deal of the effect due to temperature oscillations already referred to. In one experiment in particular in which a Grove's battery was used, with alternations at the rate of only thirty per second, this effect came out very strong, the spot swinging off the scale when the smaller battery was reversed.

Without dwelling on these, I proceed to give the results of the final set of experiments, which were in every way by far the most satisfactory.

In the three following experiments the Daniells were used as before; the alternations were made by means of the tuning-forks at the rate of 60 per second. Three wires were experimented on, a platinum, a German-silver, and an iron wire. The balancing resistance was the German silver bobbin with small resistance box, which was on the left except in the second experiment, where it was on the right. The electromotive force between D and E was now found directly by the electrometer; as a control the sensibilities are given as well. New jade-pointed platinum dippers were used, and answered admirably during the whole time the experiments were going on.

	L. B.	S. B.	Box	Bridge	Sensibilities	Electrometer.*	
(1) Pt. wire ($\frac{1}{600}$ in. diameter, .042 millim.)	+	−	20·5	4110	6	134	Very steady
	+	+	20·5	4110	17	[illegible]	
	+					2[illegible]0	
		+				110	
(2) G. S. wire ($\frac{1}{500}$ in. diameter, .051 millim.)	+	−	−2·5	3370	[illegible]	133	Very steady
	+	+	−2·5	3370	100	375	
	+					[illegible]7	
		+				118	
(3) Fe wire (.14 millim. diam.)	+	+	1·25	2090	170	[illegible]	Perfectly steady
	+	−	4·25	2090	62	[illegible]	
	+					[illegible]	
		+				114	

In the last set of experiments a higher electromotive force was used, viz. four cells of Grove and two, every thing else being as before. The same three wires were experimented upon, but with perfect success in the case of the iron wire only. In the experiments on the other two, although the electrometer readings were very steady and satisfactory, yet a steady balance could not be obtained; still it could be seen that the + + and + − balances did not differ by much. It seemed that there was, in the case of the German silver wire, a tendency towards the effect so often alluded to.

The following is the experiment with the iron wire:—

	L. B.	S. B.	Box on left	Bridge	Sensibilities	Electrometer	
(4) Fe wire (.14 millim. diameter)	+	−	4·25	[illegible]90	150	307	Perfectly steady
	+	+	1·25	[illegible]90	Off scale (i.e. >360)	805	
	+					91	
		+				271	

Using the additional data that the resistance of the metre of platinum-iridium wire on the bridge is ·075 ohm, and that Latimer Clark's Standard Cell (1·457 volt) produces a deflection on the electrometer used of about 320 divisions, we get roughly the following results (*e* denotes the electromotive force in volts between D and F, *i. e.* the $\frac{\rho}{B+\rho}$ E of the formula above; *s* denotes the radius in centimetres of the fine wire, the other letters have the same meanings as before) —

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* Electrometer deflection for Latimer Clark's Standard = 320.

	R	*c*	PE	*y*	*s*	*h* <
(1)	2.41	1.14	0.23	14	0021	$\frac{253}{10^{13}}$
(2)	1.75	1.17	0.12	16	0025	$\frac{918}{10^{15}}$
(3)	0.27	1.16	2.14	15	0070	$\frac{320}{10^{14}}$
(4)	0.31	2.69	1.32	46	0070	$\frac{668}{10^{1[illegible]}}$

The formula by which the limit to *h* is calculated is

$$h = \frac{\Delta r\pi^2 s^4}{y\mathrm{RP}^2\mathrm{E}^2},$$

where Δr is the difference between + + and + − balances (see above). In the four experiments discussed, the arrangement was abundantly sufficient to indicate a difference of a millimetre, so that Δr is

$$< \frac{75}{10^6}\text{ ohm};$$

$$\therefore h < \frac{75\pi^2 s^4}{10^6 y\mathrm{R}(\mathrm{PE})^2}.$$

Assuming, then, that the heating- and cooling-effect discussed above may be neglected, the result of the experiments is that *h* is certainly less than $\frac{1}{10^{12}}$. In other words, if we have a conductor whose section is a square *centimetre*, and whose resistance for infinitely small currents is an ohm, its resistance (provided the temperature is kept the same) is *not diminished* by so much as the $\frac{1}{10^{12}}$ part when a current of a farad per second passes through it.

With regard to the heating- and cooling-effect, it must evidently be very small, since it takes place, if at all, in something like the $\frac{1}{120}$ part of a second. It is of course possible that these alternations were at that particular rate for which the two effects would balance each other, but when we consider that the temperatures of the thin wire were very different in the different experiments (notably so in (3) and (4) with the iron wire, where the current passing was in one case more than double that in the other), and that the heating- and cooling-effect must depend on the temperature of the wire, while the other is independent of that as well as of the rate of alternation, the probability that any such balancing of the two effects existed at all is reduced to almost nothing. We may therefore look on this experiment as a verification of Ohm's law to the degree of accuracy indicated above.

APPENDIX.

While thinking how to repeat Dr. Schuster's experiments as nearly as was possible without the command of a sine-inductor, the writer of the Report was led to try a third experiment in verification of Ohm's law. If there be a periodic variation of the primary of an induction-coil, the time integral of the electromotive force in the secondary through one complete oscillation will be zero, but if the variation consist of a sharp break, although this law holds, yet the oscillation in the secondary may be divided into two parts, in one of which the maximum intensity is very much greater than in the other. If it be true, then, that a more intense current encounters less resistance than a less intense current, clearly the law above stated can no longer hold, the law has, in fact, been deduced on the supposition that the resistance is independent of the strength of the current.

It follows, therefore, that if we send the induction-currents from the secondary of an induction-coil, whose primary is made and broken by a tuning-fork, through a helix of fine wire to make sure of bringing out the effects we are looking for, then the needle of a galvanometer introduced into the secondary will be deflected so as to indicate a current in the direction of the current due to breaking the primary

Certain anomalous, and at first sight contradictory, results led the writer to study the behaviour of a galvanometer under these circumstances The result was the suggestion of a theory which explained the anomalies completely, and indicated the existence of certain other phenomena which were afterwards observed

The results are, so far as the writer has been able to learn, partly new. Although not of sufficient importance in connexion with the present subject to require detailed mention here, yet it was thought best to state the results so far as they bear on the question, reserving a detailed account for publication elsewhere *

It was found that, under the circumstances indicated above, the indication of a galvanometer is a function of the ratio of the strengths of the magnetic field when there is no current and when the currents are passing, and also of the position of equilibrium of the needle when there is no current.

Theory and observation give alike, among others, the following peculiarities:—

1. If the ratio of the magnetic forces due to the currents to that acting on the needle when there is no current does not exceed a certain quantity, then if the position of rest of axis of the needle is inclined at an angle a ($< 90^\circ$) to the plane of the coil-windings, the effect of the alternating currents is to increase that angle, so that, according as the needle is deflected one way or the other by means of the deflecting magnet, we get opposite effects

The effect is zero when a is zero

2. If the above-mentioned ratio exceeds a certain value, the position of the needle parallel to the windings (*i. e.* for $a = 0$) becomes unstable, and there now appear two positions of equilibrium of equal inclination either way to the coil-windings. Either of these the needle will take up and keep if brought there with sufficiently small velocity

The greater the ratio, the more nearly these two positions approach to parallelism with the plane of the coil-windings.

The last-mentioned phenomenon was described long ago by Poggendorff, under the name of "doppelsinnige Ablenkung," and was and has been regarded apparently as an unstable phenomenon.

The first-mentioned form of the phenomenon has not, so far as the writer knows, been hitherto described anywhere.

In repeating Dr. Schuster's experiments by superposing a small current of constant direction on the alternating current, the writer has never been able to detect any effect that could not be explained by the above results. He has not been able to use a sine-inductor as yet, so that a complete discussion of Dr. Schuster's results from this point of view has not been possible.

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* Phil. Mag [v.] vol. ii. p. 401.

The strong analogy of the phenomena to those obtained by Dr. Schuster, and the fact that it has been found possible to produce the phenomenon in three different galvanometers (it is of importance to remark that the needle was elongated in all cases where the effect was strong), must, however, be regarded as affecting the probability of conclusions drawn from experiments of this kind about the truth of Ohm's law.

Report of the Committee, consisting of the Rev. H. F. Barnes, H. E. Dresser (Secretary), T. Harland, J. E. Harting, T. J. Monk, Professor Newton, *and the* Rev. Canon Tristram, *appointed for the purpose of inquiring into the possibility of establishing a "Close Time" for the protection of indigenous animals, and for watching Bills introduced into Parliament affecting this subject.*

Your Committee has the pleasure of stating that Mr. Chaplin, M.P. for Mid Lincolnshire, lost no time in fulfilling his promise, announced in its last Report, and immediately on the meeting of Parliament introduced into the House of Commons the Bill for the Preservation of Wild Fowl, which had been prepared by your Committee, and has been referred to in its former Reports.

In order to aid Mr. Chaplin's efforts and to explain the objects of the Bill, your Committee in February last issued and extensively circulated the following statement:—

"The Committee deems it expedient to offer a summary of its former Reports, and a statement of its present views, in regard to the probability of action being taken in Parliament during the ensuing Session for the attainment of further protection of birds.

"It has long since been stated by the Committee—and the statement is beyond contradiction—that the birds which are comprehended under the common designation of Wild Fowl have, of all others, with the exception of Birds-of-prey, most rapidly diminished in numbers throughout the United Kingdom, and it cannot be doubted that their decrease is still going on.

"The reasons which hinder the Committee from recommending any legislative protection to Birds-of-prey are almost too obvious to need explanation. The Committee, while believing the existence of such birds in certain districts, and in numbers which are not excessive, is beneficial, is aware that the contrary opinion is very strongly upheld by a large class of persons, and is fully persuaded that were it possible to pass an Act for the protection of these birds, its enforcement in a single instance would give the signal for an agitation for its repeal, which would seriously damage the cause of bird-protection in general.

"On the other hand, no charge of injuriousness has ever been brought—or, if brought, could possibly be maintained—against Wild Fowl as a whole; while the employment that their capture affords to a considerable portion of the population, and their utility as an article of food to almost the whole community, render their protection highly desirable from an economical point of view. The notorious and rapid decrease in their numbers is to be ascribed to causes that may be classed under two heads.—(1) 'Indirect' and (2) 'Direct.'

"(1) The indirect causes of the decrease of Wild Fowl are attributable to the diminution of their breeding-haunts by draining, the reclamation of waste lands, and agricultural improvements generally, and with these it would of course not only be impossible, but manifestly improper, for the legislature to interfere, for with them the prosperity of the country at large is intimately bound up. So far, then, as regards *their* effects, the birds must take their chance.

"(2) The direct causes, on the other hand, are as plainly capable of control, for they are attributable to the destruction of the breeding-stock, and chiefly by the gun. As soon as birds pair in the spring they lay aside much of their habitual caution, and become easy victims to the gunner. Long after the pairing-season has begun our markets are plentifully stocked with Wild Fowl of every description, and it is obvious that every pair of birds killed at that time of year signifies the destruction of a whole brood, as well as that of its intending parents.

"Wild-Fowl shooting gives, as has been above stated, employment to a large number of men, who make a profession of it. These men, however, are accustomed to certain restraints in pursuing their vocation. They are all compelled to take out a gun-license, and many of them are aware that they are prohibited from exercising their calling in certain waters and over certain lands. The notion of restraint to them is, therefore, not new; and the Committee believes that the most intelligent of them would gladly recognize the propriety of a well-considered and stringent measure, that by effectually protecting Wild Fowl during the breeding season would secure to them a greater abundance at other times of the year.

"The Wild Fowl, for whose protection a more stringent measure is now about to be proposed, are, it is true, already named in the 'Wild-Birds Protection Act;' but owing to their marketable value being greatly in excess of the penalties which that Act prescribes—very properly, may be, in regard to the other birds it names—they enjoy little or no real protection therefrom.

"The great success which has attended the working of the 'Sea-Birds Preservation Act,' in which the penalties are much higher than in the 'Wild-Birds Protection Act,' encourages the Committee to believe that an Act on the same principle of the former, but applied to Wild Fowl, would be equally successful; and to this end the Committee recommend the passing of such a Bill as was introduced by Mr. Andrew Johnson in 1872. This Bill, it will be remembered, was the foundation of the existing 'Wild-Birds Protection Act,' but was so entirely altered in its passage through Parliament as to become useless for the protection of the group of birds it was at first intended to protect.

"The 'Wild-Birds Protection Act' may well be left as it is, since public opinion was, and is, decidedly in favour of some such legislation. Its failing to protect Wild Fowl efficiently gives no room for its repeal, but the Committee regards it as being virtually ineffective to produce any practical good.

"The Committee thinks it necessary to state once more, that of the Small Birds which so deeply engage the sympathies of many of the public, there are but few kinds which have been proved, on any good evidence, to be diminishing in numbers, and that the decrease of these is owing much less to any direct destruction or persecution than to indirect causes, such as have been already referred to, and declared to be uncontrollable by the legislature.

The diminution of such birds as the Wheatear the Goldfinch, and Linnet can be immediately traced to the breaking up and bringing under cultivation of commons, and so probably of the rest, while, on the other hand it is obvious that many kinds of Small Birds have largely increased in number owing to the spread of plantations and the security from molestation during the breeding-season they enjoy through the incessant attention given to the preservation of game

"At the same time the Committee is of opinion that some steps for the Regulation of Bird catchers might well be taken with the approval not only of the general public but of the better class of bird catchers themselves and, should success attend its present attempt the Committee would readily direct its efforts to that object

Your Committee has the gratification of reporting that the opposition which the Bill encountered in the House of Commons though seriously intended was happily overcome by the good management of Mr Chaplin and his seconder Mr Rodwell Q C A division was taken on the motion for the Second Reading, when the numbers against it were 13, and in its favour 337 —an almost absolute majority of the whole House

In deference to certain objections which were raised in Committee, Mr Chaplin consented to an alteration of the original draft Bill as regards the days when the proposed Close Time should begin and end Your Committee cannot wholly approve of this change but as it does not affect the length of the season, the modification seems not to be very important while Mr Chaplin's admit acceptance of it unquestionably saved the Bill

No further alteration was made The Bill having passed the Commons was kindly taken charge of in the Upper House by Lord Henniker and finally received the Royal Assent on the 24th of July

In congratulating all who have at heart the protection of indigenous animals in this happy result your Committee desires to point out that their most sincere thanks are due to the nobleman and gentlemen already named, as well as to others who aided the passage of the Bill through both Houses, and, in particular the efforts of Lord Walsingham deserve especial recognition

With regard to the taking of any further steps your Committee can only suggest the possibility of something being done in the direction indicated by the last paragraph of the foregoing statement The difficulties however, in the way of passing any measure for the Regulation of Bird catchers, which should be at once effectual and acceptable to Parliament, seem to be very great, and your Committee is not sanguine of the success of any immediate attempt to attain this end

The Sea Birds Preservation Act continues to work satisfactorily on the whole, though your Committee has reason to fear that its provisions have been disregarded in certain places Some time has elapsed since any prosecution under it has taken place and its enforcement in a few instances in the course of the next year may be needed to show that it cannot be violated with impunity To this object your Committee, if reappointed, will give its attention, meanwhile it may be observed that the Act is very favourably regarded in most places, and that, by authority of its third section, the Secretary of State for the Home Department has, on the recommendation of the justices of the East Riding of York in Quarter Sessions assembled, extended the "Close Time on the coast of that county from the 1st to the 15th of August

Your Committee respectfully urges its reappointment

Report of the Committee, consisting of JAMES R. NAPIER, *F.R.S.*, SIR W. THOMSON, *F.R.S.*, W. FROUDE, *F.R.S.*, *and* OSBORNE REYNOLDS *(Secretary), appointed to investigate the effect of Propellers on the Steering of Vessels.*

[PLATE I.]

THE Committee commenced operations by printing the following Circular, and sending copies of it to the Admiralty and to those shipowners with whom the individual members of the Committee were personally acquainted, or those who in their opinion were likely to assist in the investigation:—

"THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

"*Experiments on the Turning of Screw Steamers.*

"At the Meeting of the British Association in Bristol last year, a paper was read by Professor Osborne Reynolds, in which it was shown, from experiments upon models, that in a steamer when the screw is in motion, the direction in which the rudder tends to turn the ship depends on whether the screw is driving ahead or astern, and is independent of the actual motion of the ship through the water; for instance, if when a ship has headway on the screw is reversed, then the action of the rudder is the same in direction as that of a ship going astern; or if the ship have sternway on, and the screw be started to drive her ahead, then the rudder acts as if she were going ahead.

"After the discussion of the paper, Mr. James R. Napier, Sir William Thomson, Mr. W. Froude, and Professor Reynolds were appointed a Committee to carry the investigation further, and particularly to ascertain if the same results would be obtained when the experiments were made with full-sized ships.

"In order to collect sufficient data to establish a general conclusion, the Committee are anxious to obtain the assistance of such shipowners and captains of ships as may be willing to aid them.

"The Committee accordingly ask that certain trials and observations may be made, and the results, together with the name, size, tonnage, and condition of loading of the ship, as well as the depth of immersion of the screw, the date and name of the officer in charge, may be forwarded to Professor Reynolds, Owens College, Manchester, or to any of the Members of Committee.

"It is also particularly requested that the kind of screw and the number of blades may be stated, and whether the screw is right- or left-handed. By a right-handed screw is understood one in which the upper blades move from port to starboard when driving the ship ahead.

"The following are the trials requested:—

"Trial I.—That when the ship is going full speed ahead, the screw should be suddenly reversed and the rudder put hard over, as if to turn the ship to starboard of her course, and careful notice taken as to the way in which the ship turns before all headway is lost.

"Trial II.—The same repeated with the rudder set in the opposite direction.

"Trial III.—That when the ship is going fast astern the screw should suddenly be started to drive her ahead, and the rudder put hard over to the same side as in Trial I.

"Trial IV.—Trial III. repeated with the rudder in the opposite direction.

"Trial V.—That the ship should be driven full speed ahead with the helm amidships, and notice taken as to the direction in which the ship turns under the action of the screw.

"Trial VI.—That the ship should be driven full speed ahead, then the screw reversed, with the helm amidships, and notice taken in which direction the ship turns."

"*May* 3, 1876."

After sending the Circular the Committee received a communication from the Secretary to the Admiralty, to the effect that the Admiralty had ordered the experiments to be made, and that the results should be forwarded

As the result of their application to private owners, the Committee obtained the use of three vessels, upon which the following trials were made.

Experiments made with the 'Valetta,' belonging to the Earl of Glasgow, Captain R Hunter, on the 6th June, between Wemys Bay and the Cumbrae

The 'Valetta' measures 80 tons, and was drawing during the trials 5' 6" forward and 6' 6" aft Her screw, which is right-handed, is 5' 6" in diameter, and during the trials was immersed about 1', it is 3-bladed, and has a pitch of 8' 6". When at full speed the 'Valetta' makes about 9½ knots an hour.

During the trials the seconds were called out by Mr. James R. Napier. Mr Bottomley, who was acting for Sir William Thomson, watched the angles through which the boat turned, by means of a dumb compass, while the signals for turning and stopping the vessel were given by Professor Reynolds

The first trial was of the effect which the screw exerted to turn the ship with the helm amidships When at full speed she turned to port at the rate of about 7° per minute, or, as it is usually expressed, she carried a port helm However, as the speed of the engines was reduced the tendency to turn the ship to port was reduced, and when going very slow (about 5 miles an hour) the ship turned slightly in the opposite direction. When going fast the screw churned air into the water, but not when it was going slow.

The effect of the screw to turn the ship with the helm amidship, although appreciable, was not of sufficient magnitude to be taken into account in the results of the subsequent experiment And as this effect was almost the same with the wind on either bow, it was evident that, although the wind was blowing with some little force, its effect to turn the vessel was also unimportant.

These preliminaries having been settled, the ship was driven full speed ahead, then the screw reversed as suddenly as possible, and immediately the engines began to turn astern the rudder was put hard over At first on reversal the engines turned but slowly, and it was not until the boat had lost some of her way that they turned full speed astern.

Four observations were taken in this way with the helm to port, two with head to wind, and two before the wind; and similar observations were taken with the helm to starboard All four observations with the helm to port gave nearly the same results, and so with the helm to starboard.

The mean results were as follows —

With the helm ported (which, had the engines been going ahead, would have brought the ship's head round to starboard at a rate of nearly 2° a second) the vessel at first, while the screw was turning but slowly, commenced turning to starboard, and had turned through 5° in 9 seconds, she then commenced turning to port, and in 16 seconds more, when she had nearly lost all way, she had returned 13° to port or about 8° to port of her original direction, *i e* in the opposite way to that in which she would have turned had the screw been kept on ahead.

With the helm to starboard, at the end of 10 seconds she had turned through 6° to port, and in 14 seconds more, when she had nearly lost way, she had come back 14° to starboard or 8° to starboard of her original direction, that is, as before, in the opposite way to that in which she would have turned had the screw been kept on ahead.

With this ship, therefore, although the reversing of the screw did not at once reverse the action of the rudder, it greatly reduced its effect, and reversed it in time for the ship to have turned 8° out of her course before she had come to rest—that is, 8° out of the direction in which she headed on the reversal of her screw, and considering that, during the 25 seconds in which she was stopping, had her screw been kept on ahead she would have turned through some 50°, the effect of reversing the engines was to bring the ship some 58° out of the direction she might have occupied.

Experiments with the Hopper Barge, No. 12, belonging to the Clyde Navigation Trust, Captain J Bairie, on June 7, off Kilcreggan, Rosneath

These experiments were conducted in a similar manner to those on the 'Valetta,' the same members of the Committee taking part in them.

The barge when loaded carries 400 tons of mud, is 140 feet long, was drawing during the first set of experiments 11′ 6″ aft and 9′ 6″ forward, and when light, during the second set, 8′ 2″ aft or 4 ft forward. The top of the propeller is 8′ 6″ from the bottom of the keel The screw, which is right-handed, has three blades, and is 8 feet in diameter and 16 feet pitch.

The first set of experiments were made with the barge head to windward, the wind being of much the same force as on the previous day. The mud was then discharged, and the barge put before the wind, and the experiments repeated.

When loaded and going to windward with the helm amidships, the barge sheered first to port and then to starboard This was apparently owing to the screw churning the water intermittently, when the wake was apparently clear the boat turned to starboard, and when the screw was churning air into the water she turned to port.

When the screw was reversed with full way on, and afterwards the helm put hard over either to port or starboard, the action of the rudder was always reversed, and was very decided It required 1 minute for the screw to bring the boat to rest, and during that time she turned from 35° to 60°, moving slowly at first, and more rapidly as her speed diminished.

The reverse action of the rudder was therefore much more decided than in the case of the 'Valetta,' which was accounted for by the fact that the screw was reversed to full speed at once, the engineer being an old locomotive engine-driver accustomed to reverse suddenly, besides which the boat being much heavier allowed more time for the operation

When the boat was going full speed astern, the screw reversed to full speed ahead, the action of the rudder was the same in direction as if she had been going ahead, but it was very slow

When the barge was steaming full speed ahead with the rudder hard over, she turned at the rate of 1° in 1 second.

With this vessel, therefore, the effect of reversing the screw was to cause her to turn through more than 30° from the direction in which she headed when the reverse action set in; and considering that in the same time she would have turned through 60° in the opposite direction had the engines been kept on ahead, the effect of reversing was to turn her through 90° from the position she would have occupied had the engines kept on ahead.

Experiments with the Steam Yacht 'Columba,' belonging to His Grace the Duke of Argyll, June 29, in Gare Loch, the weather very fine, with little wind.

The draught of the vessel was 10 feet aft and 8′ 2″ forward. She was fitted with a Griffith's screw 7′ 1″ in diameter and 12′ pitch. The experiments were witnessed by Mr James R Napier and his son, Mr Robert T Napier. When the vessel was going full speed ahead (about 10 knots) the engines were reversed, and the helm immediately put to starboard, the vessel turned to starboard until her forward way was lost, the time between the reversal of the engines and the stopping of the ship being about 1 minute.

When the vessel was going full speed ahead the helm was set to port, and shortly after the screw reversed. The vessel turned to starboard at first, and then to port until all way was lost. The turning to starboard at first was the natural result of the helm having been ported before the screw was reversed.

In the trials on this ship no measurements were made of the angles turned through. The direction of turning, however, was the same as before, the reversing of the screw at once reversing the effect of the rudder.

In all three of these vessels, therefore, the same effect on the steering was produced by the reversing of the screw when the vessel was at full speed.

The importance of this effect may perhaps be best seen from the diagrams (Plate I.), showing the various positions occupied by the 'Valetta' and the barge compared with those they would have occupied had the screws not been reversed.

In these diagrams the directions of the vessels correspond with the actual measurements during the trials; the positions and distances travelled being estimated from the known speed of the vessels. It had been the intention of the Committee to use one of Mr Napier's pressure logs in order to ascertain exactly the positions of the vessels during the trial, but this intention was not carried out.

Diagram 1 shows the courses run by two ships after the reversing of the screw until they had lost all way compared with the courses they would have run had they continued under full steam, the helm being hard to port.

A glance at this diagram is sufficient to show what a fatal mistake it must be when a collision is imminent to reverse the screw, and then use the rudder as if the ship would answer to it in the usual manner.

But perhaps, as regards collisions, the most important result is that shown in diagram 2—namely, the positions of the ships when they have not lost more than half their way, and when, as regards the distance run, the effect of reversing the screw is but small.

As is shown in this diagram, it appears that whether the reversing of the screw reverse the action of the rudder or not, the rudder is nearly powerless to turn the ship, and that she will turn not only more rapidly, but in less room when going full speed ahead.

Before closing their Report, the Committee desire to express their thanks to the Earl of Glasgow, the Clyde Navigation Trust, and His Grace the Duke of Argyll, for the use of their vessels, and to the officers and crews who assisted in making the arrangements and conducting the experiments.

On the Investigation of the Steering Qualities of Ships.
By Prof. OSBORNE REYNOLDS.

[A communication ordered by the General Committee to be printed *in extenso*.]

THE primary object of using steam power in ships is to enable them to pass quickly over long distances. Under normal circumstances rapidity and certainty in manœuvring are matters of secondary importance, but circumstances do arise under which these powers are of vital importance. Experience has taught those who go down to the sea in steam-ships that their greatest danger is that of collision, and fogs are feared much more than storms. That there must always be danger when long ships are driven at full speed through crowded seas in a dense fog cannot be doubted; but this danger is obviously increased manyfold when those in command of the ships are under the impression that a certain motion of the helm will turn the ship in the opposite direction to that in which it does turn.

The uncertainty which at present exists in the manœuvring of large ships is amply proved by the numerous collisions which have occurred between the ships of our own navy while endeavouring to execute ordinary movements under the most favourable circumstances, and with no enemy before them. These accidents may be, and have been, looked upon as indicating imperfections in the ships or the manner in which they were handled; but it must be admitted that the ships are the best and best found in the world, and that they are commanded by the most skilful and highly trained seamen alive. And if peaceable ships fail in their manœuvres when simply trying not to hurt each other, what will be the case of fighting ships when trying to do all they can to destroy each other? If the general impression as to the important part which the ram is to play in the naval combats of the future is ever realized, then certainty in manœuvring must not only be of very great importance (this it has always been in sea fights), but it must occupy the very first place in the fighting qualities of the ship.

Now the results of the investigation of the effect of reversing the propellers on the action of the rudder appear to show that, however capricious the behaviour of ships has hitherto seemed, it is in reality subject to laws; and that by a series of careful trials the commander of a ship may inform himself how his ship will behave under all circumstances.

The experiments of the Committee on large ships have completely established the fact to which it was my principal object last year to direct attention, namely, that the reversing of the screw of a vessel with full way on very much diminishes her steering-power, and reverses what little it leaves; so that where a collision is imminent, to reverse the screw and use the rudder as if the ship would answer to it in the usual manner is a certain way of bringing about the collision. And to judge from the accounts of collisions, this is precisely what is done in nine cases out of ten. In the paper of to-day I find the following (August 22, 1876):—

"*The Fatal Collision off Ailsa Craig.*—The Board of Trade inquiry into the collision between the steamer 'Owl' and the schooner-yacht 'Madcap' was continued at Liverpool yesterday. Two passengers by the 'Owl' were recalled, and spoke to some of the facts of the collision. The night was not misty, though some rain had fallen. They saw the green light of the yacht shining brightly after the collision. William Maher, third officer of the 'Owl,' said it was the chief officer's watch at the time of the collision. There were five able seamen in the watch. Witness and the chief officer were on the bridge. One man was on the look-out from the starboard side of the bridge. His ordinary place was on the forecastle-head, but he was not placed there that night, as there was a heavy head sea, and the vessel was shipping water. His attention was called to a light by the look-out man. It was almost ahead about a mile and a half off. He could not at first distinguish whether it was red or green, as it was dim, but when he made it out to be a green light it bore two to three points on the port bow, and it was only three or four lengths off. He heard no order given to the man at the wheel when the light was first reported, but when witness found that it was a green light he ordered the helm hard aport. If the steamer had starboarded at this time she would have gone right over the yacht. The 'Owl' had been going at the rate of six or seven knots, but when she collided there was no way on her, the engines having been reversed. After the yacht went down the captain ordered a boat to be got out, but subsequently countermanded the order, on the ground that more lives would be lost, as it was not fit to go out. At the close of his examination the witness stated that he would not have gone out in a boat on such a night as that, even if the captain had ordered him—a remark which appeared to greatly astonish the nautical assessors.

He ported his helm to bring his ship round to starboard, but he also reversed his screw; and as he says nothing about having again starboarded his helm, it would appear that from the time of reversing the screw until the collision (time enough to stop the ship), she had moved straight forward or inclined to port. Had he not reversed his screw, but kept on full speed, it is clear the collision could not have happened, for at the time the collision did happen his ship would have been more than her own length away from the spot where the collision occurred. He admitted himself that to have starboarded his helm must have brought about the collision, so he ported his helm and reversed his screw, which, as it had the same effect, did bring about the collision.

From the Committee's report just read, it appears that a ship will turn faster, and for an angle of 30°, in less room when driving full speed ahead, than with her engines reversed even if the rudder is rightly used. Thus when an obstacle is too near to admit of stopping the ship, then, as was done in the case of the 'Ohio,' mentioned in my paper last year, the only chance is to keep the engines on full speed ahead, and so to give the rudder an opportunity of doing its work.

These general laws are of the greatest importance, but they apply in different degrees to different ships, and each commander should determine for himself how his ship will behave. A ship's ordinary steering-power may soon be learnt in general use, but not so the effect of stopping, there is thought to be a certain risk in suddenly reversing the engines, which any one in charge of a ship will shrink from, unless he knows it is recognized as part of his duty.

It is also highly important that the effect of the reversal of the screw should be generally recognized, particularly in the law courts, for in the present state of opinion on the subject, there can be no doubt that judgment would go against any commander who had steamed on ahead, knowing that by so doing he had the best chance of avoiding a collision, or who had ported his helm in order to bring his ship's head round to port, with the screw reversed. It seems to me, therefore, that it would be well if steps could be taken by this Association to bring the matter prominently before the Admiralty, the Board of Trade, and those concerned in navigation.

So far as the capabilities of each individual ship are concerned, there is no insuperable difficulty or risk about the experiments, and to have determined these will be a great point. When the officers know exactly what can be done in the way of turning their ships, and how to do it, the chances of accidents must be greatly reduced.

But at all events for fighting ships it is desirable that the officers should have experience beyond the mere turning powers of their own ships. When two ships are manœuvring so as to avoid or bring about a collision, each commander has to take into account the movements of his opponent. To enable him to do this with readiness, it would be necessary to have friendly encounters. A fight between two ships whose captains had never before fought, would be like a tournament between two novice knights who had never practiced with pointless spears, and such a contest, although not unequal, must be decided by chance rather than skill.

Unfortunately sham fights or tournaments between ships with blunt rams would be about as dangerous as a real fight, and the chance of an accident would be far too great for such friendly tournament, however important, ever to become an essential part of the training of a naval officer, as they were of the knights of old. For although, should war arise, the danger from want of experience may be even greater than the danger of an accident in gaining such experience by friendly fights, yet, as the chance of war is always remote, the former risk would be preferred, and this is not all.

As yet there has been no such thing as a ramming fight between steamships, so that not only are our officers without actual experience, but even the rules by which they are instructed to act (the rules of naval tactics) are based entirely on theoretical considerations, and hence are very imperfect.

Now there appears to me to be a means by which experience of the counter-manœuvring powers of ships, as well as the manœuvring powers of single ships, could be ascertained without any of the risk and but little of the cost attending on the trials of large ships, and which, if not equal to an actual fight, would be very useful as a means of training the officers.

If small steam-launches were constructed similar to the ships, so that they represented these ships on a given scale (say one tenth linear measure), and their engines were so adjusted that they could only steam at what we may call the speed corresponding to that of the larger ships, then two launches would manœuvre in an exactly similar manner to the large ships, turning in one tenth the room, and the time which the manœuvres with the launches would take would only be about half that occupied by similar manœuvres with full-sized ships. The only points in which it would be necessary that the model should represent the ship would be in its shape under water and as regards the longitudinal disposition of its weights. The centre of gravity should occupy the same position amidships, and the longitudinal radius of gyration of the model should bear the same proportion to that of the ship as the other linear dimensions. In other respects the model might be made as was most convenient. It might be made of wood, and so strengthened that two models might run into each other with impunity.

There would not be much difficulty in so strengthening the models, as the speed of the models would be very small. For instance, if the speed of the ship were 13½ knots, then that of the model would be 4½ knots.

The study of the qualities of ships from experiments on their models has not until recent years led to any important results. But this in great part was owing to the fact that proper account had not been taken of the effect of the wave caused by the ship and the consequent resistance. It was not

Diagrams for Report of B A Committee on Steering

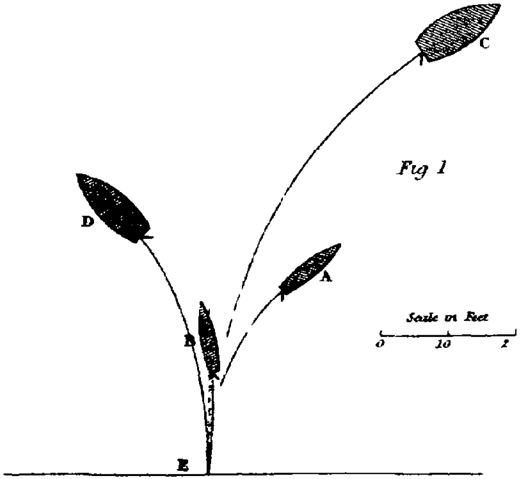

Fig 1

This shows approximately the effect of reversing the screw by the time the boats had lost all way
E is the point at which the screws were reversed
B position of Valetta after 25 when she had lost forward way
A position in which the Valetta would have been after 25 had her screw not been reversed
D position of the Barge after 1 when she had lost all way
C position in which the Barge would have been after 1 had the screw not been reversed

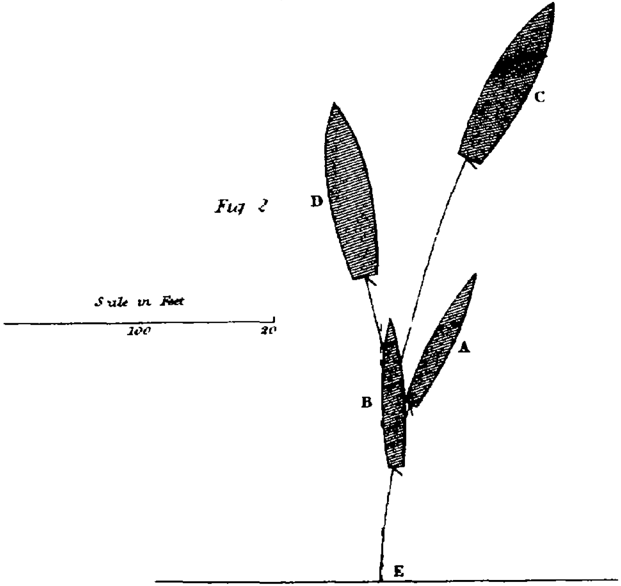

Fig 2

This shows approximately the effect of reversing the screw by the time the boats had lost half their way
E is the point at which the screws were reversed
B position of the Valetta after 12 when she had lost half her forward way
A position in which the Valetta would have been after 12 had her screw not been reversed
D position of Barge after 30 when she had lost half her way
C position in which the Barge would have been after 30 had her screw not been reversed

Engraved by W. Fench sc

known that the waves set up by the model bear the same relation to the size of the model as the waves set up by the ship do to the ship when, and only when, the speed of the model is to the speed of the ship in the ratio of the square root of the ratio of their lengths.

Since this fact has been recognized, most important information has been obtained by experimenting on models. Mr. Froude, by recognizing this law, has been able to bring the comparison of ships by means of their models to such a degree of perfection, that he can now predict with certainty the comparative and actual resistance of ships before they are constructed, and the great practical value of his results have been recognized by the Admiralty.

What I propose is virtually to extend these experiments on models so as to make them embrace the steering powers of ships as well as their resistances. The manner of experimenting would have to be somewhat altered: steam-launches would have to be substituted for dummy models; but the principle of the experiments would have to remain the same, and the speed of the launches must be regulated by the same law as that of the models.

The turning qualities of such launches might be verified by comparing them with the turning qualities of the ships as found by actual experiment, and then the models might be handed over to the officers of the ships, and they might practice encounters and manœuvres until they knew not only what they could do with their ships, but what it was best to do in order to outmanœuvre each other, and this without any cost or risk.

The behaviour of the models would be in all respects similar to that of the ships, the only difference being that the manœuvres would be on a smaller scale, and the scale of the manœuvres would be the same as that of the models, so that the step from the models to the large ships would be easy, and familiarity with the working of the ships as well as the models under ordinary circumstances would prepare the officers for using the ships in an actual fight as they have been accustomed to use the models in their friendly encounters. The scheme here proposed has its parallel in military schools. Although "autumn manœuvres" and sham fights afford soldiers a much better opportunity of preparing themselves for battle than any thing at present within reach of the sailors, still the war game appears to be growing in favour, and this is nothing more than practising manœuvres in miniature.

Independently of their value as a means of training naval officers, such models would afford a means of studying naval tactics. From them might be learnt the way in which a ship should strive to approach another of nearly equal power and speed, so as to use her ram to the greatest advantage, and of this as yet but very little can be known, and, except on models, it can only be learnt from experiments on the ships.

Important as are the laws which have been verified by the Committee on the steering of screw-steamers, it appears to me that the most important lesson to be learnt from their investigation is, that there is nothing capricious in the behaviour of these ships. To realize the value of this lesson the investigation must be followed up, and it appears that the best way to do this would be by the aid of model launches on the plan thus roughly sketched out.

Seventh Report on Earthquakes in Scotland, drawn up by Dr. BRYCE, *F.G.S., F.R.S.E. The Committee consists of* Dr. BRYCE, *F.G.S.*, Sir W. THOMSON, *F.R.S.*, J. BROUGH, G. FORBES, *F.R.S.E.*, D. MILNE-HOME, *F.R.S.E., and* P. DRUMMOND.

THE state of quiescence alluded to in last year's Report has suffered scarcely any interruption during the current year. No movement has occurred of sufficient intensity to affect any of the instruments employed by the Committee for testing the shocks. The Association will be aware that these are the seismometer, constructed on the principle of the inverted pendulum, which is placed in the tower of the parish church of Comrie, and two sets of upright cylinders, described in last year's Report, which stand on boards on the sanded floor of a building erected two years ago by the Association upon a site, half a mile west of the Comrie church, kindly granted by P. Drummond, Esq., of Duncairn, in the grounds surrounding his house. This building stands in the Comrie valley, on a boss of rock of the same kind of slate of which the adjacent hills and ridges are composed, and which can be traced into continuity with those on both sides of the valley. It was therefore expected that cylinders so placed would readily respond to any movement affecting the rocks on either side of the valley, more especially as the centre or focus from which it has hitherto been considered that the movements have emanated is at no great distance on the north side of the valley.

This expectation has not been realized, inasmuch as two slight shocks were experienced on the 14th and 16th of January, in the morning and afternoon, without affecting the seismometer or the cylinders, even those of smallest diameter, which a very slight movement is sufficient to lay prostrate in the sand. It is easy to see that a very extreme sensibility must be avoided in order to guard against the effects of other disturbing causes—as a storm of wind, a peal of thunder near at hand, or a heavy footfall on the rock outside; and hence that an undulation, propagated from a distant centre, might be so retarded by the resistance of rocky masses as not to produce the required amount of disturbance. The evidence furnished by several most intelligent and trustworthy persons leaves no doubt that on the day mentioned a very slight shock was really felt on the north side of the valley, that the movement seemed to come from the westward, and was attended by a slight noise, which died gradually away towards the south-east.

This somewhat disappointing result has led your Committee to add two more cylinders of increased delicacy to each set, and to use every effort to obtain suitable sites for other sets more to the west and north, and also further down the valley, as near Dunira, the conjectured focus, and that fixed on by Mr. Milne-Home in the former inquiry, in Glen Lednoch near the edge of the eruptive granite tract, whence the late disturbance seems to have proceeded; and, if possible, also at Ardoch, Dunblane, and Bridge of Allan, at all of which the shocks of 1873 were so severely felt. The expense would be inconsiderable, the difficulty to be encountered is the procuring of a suitable and safe site and a competent observer. Your Committee earnestly hope that these obstacles will be overcome in the course of the succeeding year.

Report on the Present State of our Knowledge of the Crustacea.—Part II. *On the Homologies of the Dermal Skeleton* (*continued*). *By* C. Spence Bate, *F.R.S.* &c.

[Plates II., III.]

As in the first part of this Report the carapace or dorsal surface of the Crustacea was considered, it is now intended to examine the plastron or ventral surface, and so complete our inquiry into the form and structure of the dermal skeleton, previous to a consideration of the internal viscera and development of the animals of the various forms in the class.

The head, or cephalon, is more clearly defined in Edriophthalmous Crustacea than in any other order; but even here the somites posterior to the mandibular ring have the dorsal surface wanting; but a clearly defined character distinctly separates them from the somites that pertain to the succeeding seven, which constitute the pereion.

This condition is less complete in *Squilla* (which M. Milne-Edwards has selected as being "of all Crustacea that in which the 21 segments of the body are the most distinct"), where the posterior somites of the cephalon as well as the anterior two of the pereion are only represented by their ventral surfaces.

This apparent incompleteness of structure, which is due rather to an economy of material, has led carcinologists to consider generally that the cephalon and pereion should be treated anatomically as one portion of the animal under the general name of cephalothorax.

Thus Dana, in writing on the "Classification of Crustacea," in his 'Report on Crustacea of the United-States Exploring Expedition under Capt. Chas. Wilkes, U.S.N.,' p. 1397, says, "In these highest species, *nine* segments and nine pairs of appendages out of the *fourteen* cephalothoracic belong to the senses and mouth, and only *five* pairs are for locomotion."

This he has taken from the Brachyural or Macrural decapod, as being the highest types of the order; but if we are to report our experiences and define the names and conditions of things according as they are represented in a single type or group, every student of any special form will draw his own conclusions from that which he has alone closely considered, and the study of Crustacea as a class in the animal kingdom must be retarded, if not misrepresented.

In studying scientifically the Crustacea as a whole, it will be found not only more correct but more convenient to describe and name the several parts of the animal by their homologous certainty rather than by their adaptation to fulfil different functions which demand a variation of form with the greater or less importance of their requirements.

The seven somites that form the cephalon are most closely associated, and difficult to be separated from those that follow, in the Brachyural type. This circumstance appears to be largely due to the powerful character of the mandibular appendages. The great strength of these organs requires such an internal development of parts that they appear to preclude the posterior somites from the power of growth; consequently they become merely sufficient to support appendages of a supplementary character.

This is very apparent in the Macrural order. In *Palinurus* the mandibles are so broad and large that their removal is almost a complete decapitation. It is therefore a structural necessity that the posterior two somites of the cephalon should be supported by those to which they are most closely approximate; consequently they are frequently found fused with the anterior somites of the pereion.

Yet in this very genus, in a young state, we have the most complete evidence of the limits that define the cephalon from the pereion, and this again from the pleon.

In the larva of *Palinurus*, as well as in the animal known as *Phyllosoma*, which is now generally accepted as being the young of *Palinurus* after some weeks' growth, the cephalon is seen to coincide with the limits of the carapace and terminates anteriorly to the seven somites of the pereion. It therefore appears that it is desirable to identify these first seven somites as belonging to the head or cephalon and that only.

The pereion, or thorax, is also composed of seven somites or segments, and this number is never departed from, even in the most depauperized condition of the animal. These several somites Prof. Milne-Edwards, in his "Observations sur le Squelette tégumentaire des Crustacés décapodes, et sur la Morphologie de ces animaux," Ann. des Sciences Nat. p. 268, 1854, says:—"In order to determine easily each of these anatomical elements of the integumentary skeleton, it is desirable to define them by a name, and I shall call them *protosomite*, *deutosomite*, *mesosomite*, or *tritosomite*, *tetartosomite*, *pemptosomite*, *hectosomite*, and *hebdosomite*, following the order which they occupy from before to behind."

In the lower types they form, as in the Amphipoda, separate and distinct segments, but in the higher groups, as we see the dorsal surface of the somites of the cephalon developed and produced posteriorly so as to cover and protect the upper part of the pereion, so we find the somites of this latter division coalesce ventrally more or less perfectly until in the Macrura and Brachyura they reach the highest degree of consolidation and are much more dense and strong than is the structure of the carapace.

This condition is gradually seen to be approached through different stages from the Edriophthalmia upwards. In the genus *Squilla* (which has many analogies with the sessile-eyed Crustacea, and appears like an enormous stalk-eyed Amphipod) three or four of the posterior somites are exposed beyond the carapace and have the dorsal arc complete and separately perfect. In the Diastylidæ we see the same, and ultimately in the genus *Pagurus*, among the Anomurous Crustacea, there is but a single somite that is not embraced within the limits of the carapace, and that is reduced to a very slender ring.

With the deterioration of the dorsal arc of each somite of the pereion the ventral arc increases in density and coalesces the more perfectly with its neighbours. This appears much to depend upon the habits and character of the animal. If it be one whose habits are perambulatory, as in *Palinurus*, the somites are strongly fused together into a strong broad sternum; whereas in such animals as *Palæmon* and *Homarus* the sternum is less strongly developed, and apparently of a more feeble character.

This depreciation of the sternum gradually goes on as we approximate the short-tailed orders, and arises from the absorption of the first joint or coxa of the leg into the general system of the animal.

In *Palinurus* the sternum (Pl. II. fig. 1), corresponding to the posterior five somites, is very broad, and the legs are very widely separated from those on the opposite side; in *Homarus*, *Nephrops*, and *Astacus* (Pl. II. fig. 2) they approximate each other so nearly that the sternum consists of a small calcareous longitudinal cord, to which the apodema are attached and receive their support.

In the Anomura, of which we may take *Lithodes* (Pl II fig 3) as an example, the coxæ of the legs are so closely compressed together laterally that, without coalescing or being fused together, they are apparently united, while the inferior part of each coxa is completely fused with its neighbour for about half its extent

This is carried still further in the true Brachyura (Pl II fig 4), where the first joints of the legs are all consolidated into a tolerably perfect mass of calcareous structure, and resemble the nature and character of a sternum

The ventral plastron, therefore, is formed of the first joint of the leg and the inferior arc of these seven somites is wanting in the true Brachyura in the adult stage, the inferior surface of the legs fulfilling the duty of the sternal plate As I have already observed, this state can be traced gradually from the Macrura to the Brachyura and it may also be observed gradually to assume this condition by following the development of the young, in which the coxal joints may be distinguished separate and individually present, and gradually coalescing as the animal increases in dimensions with age I am aware that this assertion is not in accordance with the teachings of previous carcinological anatomists, but it is one that can be proved to demonstration

Milne-Edwards, 'Observations sur le Squelette tegumentaire des Crustacés décapodes,' Ann des Sc Nat p 269, 1854 says, 'These rings exhibit all the tergal pieces, and are closed above by a carapace, except among a small number of Anomura, as the *Cenobitis*, where the seventh ring is complete We can distinguish always a ventral arc, constituted normally by two sternal and two episternal pieces, and a dorsal arc represented upon the sides of the epimeral pieces of the sclerodermic prolongations extending between the ventral and dorsal arcs of each ring, so as to enclose between them each side of the body, and to circumscribe before and behind the articular cavities destined for the insertion of the corresponding members When the rings are free, each of these arcs' extremities I shall call *arthrodials*, for the sake of being distinct, but when the *zones* are soldered together it is different The anterior arthrodial of each thoracic ring is united to the posterior arthrodial of the preceding zone, and is more or less completely united with it, so that the interarticular space situated between two such legs, instead of presenting two sclerodermic rings, lodges only a single arthrodial prolongation, which becomes common to the two approximating frames, so that it appears to depend more especially upon the last of the two rings so united To simplify the description, I shall consider these complex arthrodials as if they were formed only by their most important parts, and shall neglect consequently their anterior plate, but it should be observed that we can nearly always recognize its existence There is also an interannular symphysis which results from the formation of an interior fold of the sclerodermic lamella, a fold the two plates intimately sustain between them These processes must be looked upon as if they were produced by the simple lamella of the posterior border of one of the segments so united by symphysis

"It is always in the anterior portion of the thorax of the decapods that consolidation of the integumentary skeleton is carried to the furthest limit by the soldering or fusion of the anatomical elements"

Now what I contend is, that the structure of the somite has, as a part of the dermal skeleton, ventrally disappeared in the Brachyura, and its place has been taken by the dermal tissues of the first joint of the several legs of the pereion, and the apodema is formed in the various families of Crustacea out of parts that are homologically distinct.

In the Anomura, of which *Lithodes* may form the best example, the coxæ may best be dissected out; and it does not require any very extreme care to separate the frame of one appendage from those by which it is compressed both anteriorly and posteriorly, by which compression the joint partakes of a quadrilateral form. The plates are in many places reduced to an extreme tenuity, and practically fulfil the office of a single wall, although in reality they are produced by two lamellæ closely compressed but not united. The interior or ventral wall, that forms the sternum, is very much more strong, and extends until it meets the corresponding plate upon the opposite side. In *Lithodes* this simple condition extends from the anterior to the posterior extremity of the pereion.

In the Brachyura, of which we may take *Cancer* as the type, the walls of the coxal joint form the floor of the pereion from the anterior extremity to the fourth or tetartosomite, from which posteriorly an upright wall in the median line separates the right side from the left, and encloses the muscles of the four posterior pereiopoda within as many corresponding chambers, forming a strong arch that supports the internal viscera and precludes their sinking into the ventral cavity.

If, as I contend, this condition of the structure may be demonstrated beyond doubt, it follows that the episternal pieces lose their homological signification, as defined by Prof. Milne-Edwards, in the same way as the epimera of the dorsal arc.

The episternal plates are parts of the first or coxal joint of the legs produced as plates, valuable as supporting the articulations of the next succeeding joint with the first. It is interesting to observe that these so-called episternal plates can be traced back to large spinal processes in the young animal, and to less important processes in the pupal or third stage in the process of the development, where they can be distinctly seen as parts of the coxæ of the appendages attached to the pereion (fig. 7).

This appears to be the anatomical condition in the Brachyura, and also in some of the Anomural groups.

But in the Macrural type the ventral surface of the pereion is formed of the lower arc of the several somites which belong to this division of the animal. Some slight variations of form and appearance exist in separate genera. In *Palinurus* the anterior part of the sternum is narrow and longitudinally longer than broad, while the posterior part gradually increases in width from the anterior to the posterior extremity. Each somite is completely fused with those with which it is in contact at the centre, while deep lines of fissure define their separation on each side, the posterior process of which somites corresponds analogically with the so-called episternal plates in the Brachyura, but homologically they are distinct, being, in this form, parts of the true somite, and not a portion of the coxa of the leg incorporated with it (Pl. II. fig. 1).

In the genus *Astacus* the sternal plates are all narrow, being scarcely broader posteriorly than they are anteriorly, while in the genus *Homarus* the sternal plates are still more narrow and less important. This appears to be the general characteristic of the ventral plates in *Nephrops*, *Palæmon*, *Crangon*, &c., but more delicately and feebly constructed, so far as the external conditions; but in the lower forms of Crustacea, such as the Amphipoda and the Isopoda, the sternal plates are broader than they are long, and consequently the several pairs of appendages are widely separated from each other, correspondingly so throughout the entire length of the pereion.

The internal structure in the Podophthalmous types is more complex than the same parts in the lower or sessile-eyed forms.

In *Astacus*, where the structure is perhaps more distinct, the margins of the approximating somites are seen to be compressed together, the anterior margin of one with the posterior of the next, and to thin out and ultimately combine together into a thin wall or plate of partition, separating the several sets of muscles connected with appendages belonging to one somite from those belonging to adjoining ones. Independently of being walls of separation they are points of attachment on which some of the muscles are securely fixed. Not only do they exist near the lateral margin, but continue inwards and extend forwards until they reach the corresponding processes on the opposite side of the pereion, and also anteriorly until they unite with a similar system of osseous plates in the adjoining somite. Each plate appears to form a basis on which a strong muscle may take root on either side, thus forming a fulcrum for muscular power and a means of separating one set of muscles from another. In *Palinurus* these plates, when they approximate the median line, turn over and lie horizontally with the longitudinal axis of the animal. These plates thus displayed form a perforated floor on which the larger and more important internal viscera rest. This osseous system continues from the postmandibular somite persistently to the penultimate somite of the pereion, where it is united with the floor of the pereion by a central and lateral point of contact.

The anterior margins of the two halves of the first somite of the pereion meet together in the centre and form an oblique and prominent bridge that supports the posterior portion of the stomachic viscera, while the internal processes of the apodema, as they are termed by M. Milne-Edwards, that spring from the posterior two somites of the cephalon, are closely attached to, and at their extremities are perfectly ossified with, the lateral and central parts of the apodema of the anterior somite of the pereion, a point of union that the structure of the animal requires to be of considerable strength, as the enormous processes of the internal movable mandibular plates occupy so large a space that their points of attachment necessitate a structure of greater resistance and strength than the impoverished character and condition of the two posterior somites of the cephalon are capable of securing to them, without the additional support which they receive from a union of a more or less perfect character with the anterior somite of the pereion.

The apodema that support the internal viscera are perforated by a series of foramina that, while they correspond in form on each side of the central line, yet differ in size and shape according to the relative proportions of the organism that are connected with them. The dimensions of the foramina, through which the muscles move the large and more important appendages, are larger and more conspicuous than they that relate to those that move the less efficient and smaller organs of the body. Thus we find that, generally, the largest and most conspicuous foramina correspond with the third somite of the pereion in *Palinurus*, *Astacus*, &c., whereas in those genera where the great prehensile hand is produced by the increased growth and proportions of any other pair of appendages, the foramina in the apodemal plate correspond with the increase of their dimensions.

In the Anomura, of which we will take *Lithodes* as the type, the internal and apodemal plates do not project so as to reach the corresponding processes on the opposite side. There are only six somites fused together on the ventral surface, or, I should rather say, contributing to the formation of the sternal plastron; the seventh somite exists as a separate and distinct ring, both dorsally and ventrally free from ossified union with the anterior somites of the pereion.

In this genus the sternal plate, as an anatomical part of the animal, is wanting, or represented only in a theoretical character by the median line of fusion.

The coxæ are existent without fusion with each other for some extent, visible on the ventral surface before their close contact reaches ossification so perfect that their line of union is represented by marks of depression only on the external surface, and corresponding crests or ridges on the internal surface. Dorsally this appears to be similarly repeated, and the lines of contact are imperfect in their fusion until the plates have thinned out into a membrane. Laterally the walls of the coxæ of the several pairs of appendages are so closely compressed that their lines of union are with difficulty determined not to be fused together. That they exist for some distance as thin plates in close contact is certain, but they ultimately reach a point where the distinction is lost in perfect ossification. The internal plates approach the corresponding ones on the opposite side in the first two somites only, which form a bridge that supports the posterior extremity of the stomachic region, behind this the ventral surface rapidly widens, but the apodema or internal plates abruptly terminate, leaving a large expansion for the internal viscera to occupy.

In the Brachyura the central fusion of the sternal plates is still more perfect, and the ventral portion of the somites appears to be covered entirely; this exists in a vertical plate that appears to be formed by being compressed between the coxæ of the corresponding pairs of appendages, the external surface of which may be traced to a sinus (Pl. II. fig. 6 *a*) that opens in the median line between the third and fourth somites. The segments of the pereion in this order of Crustacea, as may be seen in the genus *Cancer*, are very closely compressed, and apparently overlap each other dorsally, while ventrally the several appendages, from their proportionate dimensions, preclude the possibility of too close a contact. The consequence is that the general arrangement of the entire muscular system that moves the appendages or the pereion, together with the osseous structure that supports them, is arranged in a circular form, the superior or extensor muscles forming the upper or dorsal arc, and the inferior or flexor muscles forming the lower or ventral arc. The plate, therefore, that is produced internally in the median line is in continuation with the interior portion of the ventral floor of the pereion, and is the homologue of the sternal plate. This tendency of the muscles to form round a common osseous centre appears to give a similar relation of the several somites to one another. Thus we find that the apodema narrows the dorsal extremity corresponding to each somite to such a degree that a deep notch or fold takes place over the fourth pair of appendages, at which point the curvature is greatest (fig. 5). It is this circular portion of the muscles that facilitates that peculiar arrangement by which the posterior two pairs of legs in *Dromia*, *Dorippe*, &c. appear to be attached to the dorsal surface of the animal, which enables them to adhere to floating pieces of wood or weed, or securely attach themselves to univalve shells by means of these appendages.

The *pleon*, or that portion of the animal to which the appendages are attached which, in their most perfect condition, are adapted for swimming, undergoes a great variety of forms. It is perhaps most perfectly developed, in accordance with the value and usefulness of its parts, in the Macrurous division of Crustacea.

In the Edriophthalmia it is perhaps more simple in character, but it is in the Anisopoda, or that intermediate stage that unites the Isopoda and the

Amphipoda, that we are enabled to determine the true homological relation of one part to the other

In all Crustacea above the Entomostracous forms the several somites are distinguished by a dorsal and a ventral arc The dorsal is invariably a hard, strong, and osseous plate. The ventral arc is mostly represented by an osseous band that reaches across the animal, and is united anteriorly and posteriorly to the contiguous somites by large and flexible membranous tissues The dorsal arc is wide, and dips under the adjoining one anteriorly in all except the second somite in the Macrura, which overrides the plates of the adjoining somites both anteriorly and posteriorly This arrangement does not exist in the Edriophthalmia, because, there being no dorsal carapace protecting the pereion, all the somites have a separate and distinct dorsal arc. The consequence is that each somite posteriorly overlaps the anterior margin of the next succeeding ring, except the first or anterior somite of the pereion, which overlaps anteriorly the posterior margin of the cephalon and posteriorly the anterior margin of the second somite of the pereion In each of these orders of Crustacea we find that the greatest power of flexion is given to the animal at these points.

In all the distinguishable somites of the Edriophthalmia, from one extremity of the animal to the other, each separate one is observed to support laterally a large plate These, in the pereion, are firmly attached to their respective somites, but not ossified to them, in the pleon they are so united by ossific matter that one part is not capable of being separated anatomically or distinguished in structure from the other It is these parts in this particular division of Crustacea that originated the idea of the theory of the Crustacean somite as enunciated in 1830 by Prof Milne-Edwards. The fact that the supposed side-plates, or epimera, were merely the first joint of the normal legs or appendages has been satisfactorily demonstrated in the Edriophthalmia, as far as relates to the somites of the pereion, but hitherto the relation of the side-plates of the pleon to the normal condition of the mobile appendages had not been demonstrated until the structure of the dermal anatomy of the genus *Apseudes* had been made out*. that "one interesting and, as far as we know, unique feature in these Crustacea yet remains to be noticed. The segments of the pleon have the lateral walls (long known as the epimera of Milne-Edwards, called also the pleura by many authors) existing as articulated appendages, demonstrating two important features in the homologies of these parts. 1st, that they are all really portions of the appendages, being the first joint or coxæ of the pleopod . . . and 2nd, that, since the peduncle consists of three joints, the second branch in the appendages of the pleon, as in other parts, is shown to take place invariably at the extremity of the third joint." In the Macrura and higher Stomapods the coxal joint of the several appendages is united to the dorsal arc in a very perfect and complete state of ossification, with the exception of the first somite, where there are no appendages, and the sixth, where the coxa is free and articulates, with small lateral motions, with the dorsal arc of the respective somite. The seventh somite (*telson*) is reduced in character and altered in form; it universally covers and holds the terminal exit of the alimentary canal, the inferior arc of which is represented by a membranous tissue In the Amphipodous order of Crustacea the fifth and sixth somites carry their appendages with free coxæ, and the terminal somite exists only in the form of a scale very liable to vary in shape, or separated into two of minute dimensions. In the Isopoda the sixth somite only has the coxæ free, and the appendages attached to them bear no very distant analogy to the homologous pair as they exist in the Macrura. In numerous genera of Isopods the sixth somite is developed to a very large size, and either absorbs or displaces the terminal somite or telson altogether, which in some genera is represented by a notch or cavity only, while in many others it is produced to a point or terminates in a smooth and even margin with the exception of some of the *Anisopod* genera, the telson probably is absent throughout the order of Isopods.

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* Hist. Brit. Sessile-eyed Crust. vol. ii. p. 140 (*Apseudes*).

The form of the pleon in the Brachyura bears as close a resemblance to that of the Isopoda belonging to the tribe *Liberatica* as that of the Macrura resembles *Parasitica* in the same order.

The coxæ or side pieces, as they have been very commonly supposed to be, are, in the Brachyura, very densely ossified with the dorsal arc, and this to such an extent in the male animals that it is very difficult to determine their presence. In the female, where the lateral development assumes a greater extent, the line of union is capable of being determined by a marked depression that defines the limit of the somites and the altered position of the appendages, but that they are homologically present in both sexes there can be no reasonable cause of doubt. This, I think, may be generally depended on—that the more the coxa departs from the normal type of the joint, as we see in the Macrurous Crustacea, and becomes associated with the dorsal arc of the theoretical somite, the more the character of the appendage becomes simplified or depreciated but, on the other hand, the more intimately it becomes associated with the ventral arc the more it becomes developed in its connexion with the requirements of the animal and any variation of form is dependant on the value of its position and the habits and necessities of the creature. Thus we find that all the appendages of the cephalon and pereion are associated with the ventral arc in the Brachyura and Macrura, but in the Edriophthalmia those of the pereion are associated with the dorsal arc, whereas the appendages of the pleon are, in all divisions of Crustacea, so intimately associated with the dorsal arc that in most cases the coxa is incorporated with the somite, and generally the remainder of the appendages disappear or are reduced to merely a rudimentary condition, useful in some females for the attachment of ova, while in the males they disappear more or less completely, or in the general conditions of life become variated so as to fulfil special requirements or peculiar functions.

Thus the 21 somites of which the typical Crustacean consists each supports in its most simple condition a single pair of appendages, and if we were to suppose every segment of the animal to be reduced to its most simple character, and the appendages attached to each segment reduced to the most simple form of articulated limbs, and all of them uniform in size, the animal would bear a close analogy to a segmented annelid.

This we must take as the archetype of a crustaceous animal, and assume that the appendages are attached to the spaces that exist between the dorsal and the ventral arcs of each somite. Thus when we observe any extreme variation of form, we must consider the earliest and most simple condition of the appendage in the archetype, and it is not at variance with our idea of progression to assume that any great departure from the most simple type that appears to be common to the entire or a large portion of the subkingdom of Crustacea had its origin at an earlier period in the history of its evolution.

The organs of vision are common to all the Crustacea, and in those species that are blind in their adult condition, the eyes are generally well developed in the younger stages.

The eyes are, independent of their value as organs of vision, of great importance in the study of the natural arrangement of the various forms of animals in the subkingdom They vary in form and character from the most incipient ophthalmic spot to the compound eye erected on pedestals, but whether single or compound, solitary or in pairs, their form and composition is generally so persistent with certain forms and characteristics of the life and habits of the animals that the few exceptions to the general rule do not preclude them from being an important and valuable means of arranging Crustacea

This was first appreciated by Leach, in 1815, in his Classification of the two great divisions of these animals. He arranged them under the two great heads of PODOPHTHALMIA and EDRIOPHTHALMIA— or those Crustacea that in their adult stage have the eyes elevated on peduncles or footstalks, and those which have them sessile or without any footstalk To this general observation the exceptions are very few Among some genera that inhabit subterranean passages and live in the dark, the footstalks are so reduced in size that they can only be said to exist theoretically, inasmuch as we find them well exhibited in their young and early stage. We must therefore assume that they have depreciated from their normal condition through adverse circumstances. On the other hand, among the Edriophthalmia we have the genus *Tanais* with its compound eyes elevated on their own pedestals, differing from the pedunculated form only in being rigid and incapable of movement

In the Podophthalmia the eyes are implanted at the extremities of appendages that are supported upon a separate and distinct somite

In 1837 Prof Milne-Edwards demonstrated this to be the case in the genus *Squilla*, in 1854 he states, in his "Observations sur le Squelette tégumentaire des Crustacés décapodes," Ann. des Sciences Nat. p 254, which I have since confirmed (fig. 7), that in the genus *Palinurus* (the Langouste) "l'anneau ophthalmique est parfaitement distinct, et se présente sous la forme d'une pièce sclérodermique impaire, courte et large, située en avant du bord frontal de la carapace, et au-dessus de l'anneau antennulaire. Les appendices ophthalmiques, ou tiges oculaires, naissent des deux extrémités de ce segment, et se composent chacun de deux articles une pièce que j'appellerai *basophthalmite*, et une seconde, qui porte à son extrémité la cornée transparente, et qu'on peut nommer *podophthalmite*."

Milne-Edwards in the same manner shows how in several species of *Palinurus* the antero-median portions of the carapace project more or less completely over the ophthalmic ring, and so (*l. c.* p. 255) "par conséquent, ouvert à ses deux extrémités latérales pour le passage des tiges oculaires, et l'espèce de cadre ainsi constitué autour de la base de ces tiges forme la portion fondamentale de l'orbite ou *trou orbitaire*."

Thus the orbit in Crustacea is formed by the third or second antennal somite reaching over and coming into contact more or less perfectly with the first antennal somite. The greater or less in degree the separation between the second and third somite above the ophthalmic somite the more or less complete is the orbit in which the eye is protected. This varies in different genera, and is very complete in the genus *Cancer* (Pl. II. fig. 9), where the ophthalmic somite is enclosed entirely by the union without fusion of the antero-dorsal projection of the posterior antennal somite with the anterior antennal somite; but, according to Milne-Edwards, in the genus *Palinurus* this perfection of the orbit varies. In *P. vulgaris* (fig. 8) the ophthalmic somite is naked, in *P. frontalis* it is covered, and in *P. verreauxii* it is enclosed; and Milne Edwards observes that many other Crustacea offer examples of these three organic forms. For instance *Pagurus, Cenobites* and *Callianassa* have the ophthalmic somite exposed as in *Palinurus vulgaris*. *Homarus, Crangon, Palæmon, Galathea, Lithodes, Ranina*, &c. have this somite covered as in *Palinurus frontalis*; and *Homola* has the ophthalmic somite enclosed.

In *Astacus* the ophthalmic somite is reduced to a minimum extent, and it is only partially protected by the anterior projection of the rostrum of the carapace.

Milne Edwards says that independently of the somite, the ocular appendages are formed of three articles or joints, a coxophthalmite, a basophthalmite, and a podophthalmite, but that ordinarily the coxophthalmite is rudimentary or obsolete.

In the genus *Alpheus* (fig. 10) and other fossorial marine forms the ocular appendage is reduced to an extent that allows the carapace to cover it entirely; but in the larval form the organ (fig. 11) is seen to be as well developed and as prominent as that of any aquatic species. It is in this way we may assume that the sessile condition of the organ in the Edriophthalmia (fig. 12) has been attained, first by the contraction or reduction in extent of the ocular appendage, so that the anterior wall of the carapace shall cover it, and then by the more intimate connexion of the organs with the structure of the parts that protect them, and ultimately with entire absorption of the ocular appendage, the eye receives its support from the walls of the carapace alone.

Even here the organs are themselves still liable to depreciation; thus those that exist where light is absent (which inhabit deep wells, subterranean caves and excavations in the depths of the ocean) first lose the dark colour of the reflecting pigments, which is soon followed by a degeneration of the character and appearance of the lens. In *Ampelisca*, an Amphipod that lives in muddy bottoms, all the lenses but two have disappeared, and the pigment has become red; in the well shrimp (*Niphargus*) the only trace of an eye exists in some yellow-looking pigment; while in the Podophthalmia we find that *Polycheles* (Heller), a prawn from the Adriatic closely allied to (if not identical with) *Deidamia* from the deep-sea dredging of the 'Challenger' expedition, and another from the Mammoth Caves of America, as well as *Nephrops Stewarti* (Wood Mason) from Formosa, have the eyes wanting as organs of vision, while they retain them as obsolete appendages.

The second pair of appendages is the first pair of antennæ. These M. Milne Edwards has named (for the sake of convenience in distinguishing them from the second pair) the *antennules*. But as this term is one, in itself, that is suggestive of diminutiveness and inferiority, I think that it had better be employed as little as possible. Generally speaking, this pair is smaller in proportion than the second; but usually it is of a more highly organized structure, and diminishes in dimensions as it becomes important in its functional properties.

The appendage consists, in its normal condition, of three joints, homotypical of the coxa, the basos, and ischium of the true legs in Crustacea. These three joints support an extremity that is very liable to vary in form, number of branches, and general appearance; but one of them must be regarded as the primary branch, inasmuch as it is invariably furnished with a set of organs peculiar to it, and found on no other part of the animal. These are slender, delicate, membranous, thread-like processes, that are liable to vary somewhat in form and size, but are all but universally present in aquatic Crustacea, and which, from their supposed connexion with the sense of hearing, I have elsewhere denominated *aural cilia*. The secondary branch is less important, and frequently divides into two or more rami. Sometimes these flagelliform branches are reduced in size to a minimum amount, and this generally corresponds with the highest character of the organ; for it appears to be in inverse ratio—the longer and more extensive the character of the terminal flagella, the less developed is the structural condition of the organ of sense contained within the peduncle, and, on the other hand, the more developed the sensational organ, the feebler and less numerous is the organism and less antenna-like is the general character of the distal portions of the appendage. To this very constant condition in the aquatic forms of Crustacea we have a variation in the terrestrial species. In the genus *Oniscus* and allied forms of Isopoda, as well as in the littoral varieties of Amphipoda, such as *Talitrus*, *Orchestia*, &c., the first pair of antennæ are reduced to a minimum proportion consistent with their presence, without any increased importance in the structural condition of the peduncular joints, as far as I have been able to ascertain.

In the highest types of Crustacea the coxal joint is considerably enlarged (*vide* pl. i. fig. 8 *b*, Report for 1875), and contains within it a complicated chamber and highly developed organ of sense; while in the Macrurous forms a less complicated chamber exists, with an external opening into which small grains of sand find their way; in others, as first shown by Professor Huxley in a species of Stomapod, well-developed forms resembling otolithes are present; this Dana has observed, and I have been enabled to confirm in a species of *Anchistia* from Australia (Pl. II. figs. 13 & 14).

In some genera, as *Mysis* among the Stomapoda, they vary in form according to sexual distinction. The male animal has the two terminal flagella feeble and slender, while a fasciculus of strong hook-formed hairs are planted on the inner and lower angle of the most distal extremity of the second joint of the peduncle, while a similar but less powerful group of spine-like hairs are planted on a strongly projecting process on the inferior distal extremity of the first joint (Pl. II. fig. 15). There are other hairs implanted on the lower margin of this joint of a very delicate ciliated character. The peduncle of this antenna is very powerful, and there can be little doubt but that it is useful as an organ of prehension, most probably employed in securing the mate. These several facts are demonstrative evidence that the first pair of antennæ are connected with the acoustic properties.

Of this I purpose treating, as well as discussing the observations made by Dr. Hesen in his researches (published in 1864) on the auditory organs of the Decapod Crustacea, when I report on the internal structure of the animal.

Contrary to a possible condition of all other appendages, the coxal joint of the first pair of antennæ is never absorbed into or fused with the sternal portion or ventral arc of the somite to which it belongs.

The third pair of appendages consists of the second pair of antennæ. These are often very large and powerful organs, frequently adapted as weapons of offence and prehension. They consist of two divisions similar to the first pair, that is, a peduncular and flagelliform part. Of these the peduncular consists of five joints, the flagelliform extremity of a strong, solitary, multiarticulate rod in its most normal condition; but it very frequently varies in form, but never increases in the number of its branches.

In the Macrura generally the flagellum is produced, on an average, to about the length of the animal, and is mostly multiarticulate in its character, the small *articuli* varying in number and length. Sometimes, as in *Scyllarus* (fig. 16), it consists of a single disk-like plate. But the greatest tendency to variation in form exists in the Amphipod and Isopod Crustacea. In some of these it reaches to a very considerable length and is multiarticulate, but in others it is reduced sometimes in length, sometimes in form. In *Talitrus* it is reduced without alteration of character to a very small size, so it is in *Hyperia*, but while in the former it stands on a long and powerful peduncle, in the latter the peduncle is short and feeble In *Chelura* the flagellum is broad, flat, and unarticulate, and fringed with a dense mass of soft hairs. In *Podocerus* and a few closely allied genera the flagellum is formed of one or two large articuli or joints, and the hairs are reduced in number but increased in strength, and become hook-like spines In *Corophium* the whole antenna bears a near resemblance to a true walking-appendage, and is no doubt used to assist in progression, as is mostly the case with Crustacea that inhabit tubes and hollows of their own excavation or building.

The peduncle of this antenna is invariably formed of five joints These are —

The first, for which Professor Milne-Edwards has suggested, in the memoir quoted, the name of *coxocerite* This contains within it an organ of sense which Milne-Edwards believes to be connected with that of hearing, but I think there will be little difficulty, when reporting on the internal anatomy, in showing that it is connected with the olfactory sense. In the Amphipoda and Isopoda, with but few exceptions, such as *Talitrus*, *Orchestia*, &c, the first joint is free, but so it is in many of the Macrurous forms, such as *Astacus*, *Homarus*, &c But in *Palinurus* it is strongly built into and fused with the ventral arc of the fourth or next approximating somite These parts are still more closely associated in the Brachyurous form, so that it is difficult to determine where the antennæ end and the region named by Latreille the *epistome* commences

The second joint, named by Milne-Edwards the *basocerite*, is generally short and supports at its extremity a movable squamiform appendage, to which the same carcinologist has given the name of *scaphocerite*. This appendage is constant in all Macrurous forms of Crustacea. It appears to be wanting in the genus *Palinurus* only, but even here it is represented, as I had the opportunity of showing, in the Report on "The Marine Fauna of Devon and Cornwall," by a figure of it incorporated in the integument of the succeeding joint, as if it were absorbed by pressure against it.

This appendage (scaphocerite) does not exist in any of the forms higher or lower than the Macrura, except *Pontia* (Pl II fig 18) in the Entomostracous forms, and that peculiarly interesting little Isopod *Apseudes*, in which genus we find a small squamiform plate resembling and probably homologous with it.

The third joint the above author has named the *ischiocerite*, and the two following the *mesocerite* and the *carpocerite*, while the multiarticulate flagellum, which corresponds "to the penultimate joint of the thoracic member," he calls the *procerite*. It is rather a curious oversight that, while Milne-Edwards has been most particular in identifying the several parts of the second antennæ by an especial name, he has omitted to give any to those of the first pair of antennæ, the three joints of the peduncle of which are homotypical of the coxocerite, the basocerite, and the ischiocerite of the second pair of antennæ, but the flagellum, instead of being homotypical of the procerite, represents the mesocerite and the successive articulations

In the Macrura generally the joints of the peduncle are distinctly separated from one another; but in some of the higher forms, such as *Astacus*, *Homarus*, and *Palinurus*, they exhibit a tendency to crowd and coalesce with each other, that is increased in the Anomura, and carried to such a degree in the Brachyura, that in some, as in *Menethœus*, *Leptopodius*, *Maia*, &c., the first two or three articulations are not to be distinguished from the surrounding structure except by the position of the olfactory opening.

In the Canceridæ all the joints of the peduncle (Pl II. fig 17) are fused together and are so closely implanted in the structure of the facial portion of the two first somites that they assist more or less perfectly in forming the walls of the ocular orbit, the several variations of which are made use of by Alphonse Milne-Edwards as a means of assisting him to distinguish the several genera of the Cancerides from each other, and which, from their easily accessible position, might be found a convenient aid in assisting to determine genera among fossil forms.

Among the Amphipoda all the several articulations are distinct from one another and from the body of the animal, and the olfactory organ is carried in a long tooth-like process that is open at the extremity This arrangement is not so distinct in the Isopoda and the terrestrial Amphipoda It also disappears in certain abnormal forms of aberrant and parasitic Isopoda

The next succeeding, or fourth pair of appendages is among the most constant in the subkingdom Within certain limits the mandibles vary with every genus, and would form when detached a very certain means of generic diagnosis. In the most simple condition, where they approximate in form to that of the peduncular portion of the second pair of antennæ, they exist in *Nebalia* (Pl III fig. 19). But, as stated by Milne-Edwards ("Squelette tégumentaire des Crustacés décapodes," p 256, Ann des Sc Nat 1854), the mandibles are not appendages simply applied against the mouth, but occupy of themselves a special cavity, flanking on either side the entrance to the alimentary canal, which, when the two are brought into juxtaposition in the median line, they generally close The mandible in *Nebalia* (Pl III. fig 19) is formed of a long osseous process that projects internally, and is secured by muscular attachments to the internal dorsal surface of the carapace, a large obtuse-pointed process is projected inwards across the mouth, and antagonizes with a corresponding process on the one opposite. This process is very liable to vary in form in different genera Beyond this process, at the root of it, springs a cylindrical osseous continuation, at the apex of which are articulated two equally long and important joints. These two joints are homologically the same that form the small appendicular appendage attached to the mandible of all Crustacea (Pl III. fig 21) so persistently that their absence is a fact to be recorded in the structure of special genera, such as *Talitrus* and *Orchestia* among the Amphipoda. In a scientific point of view, this appendage must be part of the primary portion of the theoretical limb This idea also receives confirmation in the form of the mandibles of the genus *Pontia* of Milne-Edwards, where may be observed a secondary ramus attached to the extremity of the first joint of the appendicular branch (Pl III. fig. 20).

This appendage M. Milne-Edwards, in the nomenclature that he has given, proposes to name the *protognath*, but the first joint, or true mandibular portion, he calls the *proto-coxognathite*, and the second joint the *proto-basognathite*, and the other joints in succession after the names of the respective joints in the ideal appendage which they homologically represent. While wishing to give all honour to that distinguished carcinologist for the care and exactitude in determining the several parts of the structure of a crustacean by means of a distinct nomenclature, it is with regret that I am compelled to admit that they would be more practically useful, and consequently more generally adopted, if the terms were less lengthy, and with a less redundancy of expression. I shall therefore in this report, as far as possible, adopt the terms of definition proposed by Milne-Edwards, but omit generally the appendicular term so constantly repeated by him. Thus the terms coxa, basos, ischium, mesos, carpus, propodos, and dactylos will be sufficient for whatever appendage I may be writing about, without repeating the name of the appendage, whether *gnathite, podite, cerite*, or other, after that of each individual joint.

But it is only just that Professor Milne-Edwards's reasons for adopting these terms should be reported in his own words. Writing of the appendages of the mouth, he says:—

"Depuis les beaux travaux de Savigny sur la bouche des animaux articulés, on s'accorde généralement à considérer tous ces organes comme étant des homologues des pattes, mais on les distingue presque toujours entre eux sous les noms particuliers de mandibules, machoires proprement dites et mâchoires auxiliaires ou pattes-mâchoires, ces désignations spéciales sont quelquefois utiles, mais, dans la plupart des cas, il est préférable de considérer tous ces appendices masticateurs comme des membres d'un seul et même groupe organique, de leur donner un nom commun, et de spécialiser ce nom par l'adjonction d'une racine adjective, on pourrait de la sorte les appeler protognathe, deutognathe, etc. et faire entrer le mot gnathite, comme racine constant, dans la composition des noms appliqués à chacun des articles, ou éléments sclerodermiques, dont ils sont formés. Ces gnathites seraient différenciés à l'aide d'un certain nombre de racines adjectives indiquant leur position dans le membre, et lorsque dans les descriptions zoologiques on aurait à en parler, on pourrait se borner à ajouter aux noms composés, qui appartiendraient en commun à tous les termes de chaque série des pièces homologues, un numéro d'ordre pour indiquer leur position dans cette série organique, c'est-à-dire les appendices auxquels ils appartiennent. Ainsi je proposerai d'appeler *coxognathite, basignathite, mésognathite*, etc. les articles qui, dans la série des appendices maxillaires correspondent au *coxite*, au *basite*, etc. dans les autres membres, et d'appeler premier *coxognathite* la pièce de cet ordre qui appartient au *protognathite*, deuxième *coxognathite* celle qui appartient au *deutognathite*, etc. Ce système de nomenclature est à la fois si bref, si commode et si éminemment significatif, que je demande aux carcinologistes la permission d'en faire usage non seulement dans les considérations morphologiques dont je m'occupe ici, mais aussi dans les travaux taxologiques que je me propose de publier prochainement."—"*Squelette tégumentaire des Crustacés décapodes*," *Ann. Sc. Nat.* 1854, p. 267.

The mandible or protognathe is sometimes very large, and at others reduced to a rudimentary condition. In *Palinurus* it occupies on each side one half of the breadth of the animal, and to remove the two mandibles is almost to decapitate the animal. In some of the parasitic forms it is reduced to a rudimentary condition. In the female of *Anceus* (*Pranisa*) it, with other appendages, coalesces to form a probing or lancing instrument that projects like a proboscis beyond the head; while in the male of the same genus the mandibles are situated on the anterior margin of the head, and stand projecting like a pair of rude irregular antennæ. But in this animal the mouth is closed, or at most represented by a microscopic aperture, as it, in this stage, exists without eating.

In most forms of Crustacea the space that exists between the anterior margin of the protognathe or mandible and the posterior margin of the epistome is occupied by a fold of the membranous tissue that encloses the oral cavity. This fold is frequently ossified and projected into a strong labium or movable lip It is very conspicuous in young animals, and frequently in adult forms, particularly among the Amphipoda It is represented by two small osseous disks in *Palinurus*, and a single small triangular plate in *Cancer* Corresponding with this labium posteriorly is another that protects the opening between the mandibles in this direction This is also supported frequently by osseous plates but this organ is not constantly developed beyond a limited extent, except in a few instances In *Palinurus* it consists of a central osseous plate, having a suture through the median line, from this base it projects in two long membranous sacs, supported on the outer or posterior surface by one or two osseous plates (Pl III fig 22) It is this organ, it appears to me, that represents and is homologous with the lip-plate or metastoma in *Eurypterus*, *Pterygotus*, &c , that has been so fully described by Huxley, Woodward, and Salter

The fifth or next succeeding pair of appendages is that which Prof Milne-Edwards has called the deutognathe It is what has been known in popular carcinology as the first pair of foot jaws, and first maxilla or siagnopoda in the 'History of the British Sessile eyed Crustacea,' the latter name being suggested by Prof Westwood "as the Greek equivalent for the Latin name of the five pairs of appendages succeeding the mandibles, which were collectively termed *pattes-mâchoires* by Cuvier, Savigny,' &c

The deutognathe in all known forms of Crustacea exists in the adult stage in an embryonic condition, it is small in size, feeble in power, and consists, in different genera and families, of a varying number of thin squamiform plates Each joint of the typical limb, as far as present in the adult condition (Pl III fig 23), offers no very exceptional distinction from the same in the embryonic stage (fig 24)

The *tritognathe*, or sixth pair of appendages, supports the idea of the adult form bearing a close resemblance to that of the zoea or embryonic condition still more decidedly (Pl III figs 25 & 26)

The seventh pair of appendages, the *tetartognathe* of Milne Edwards's nomenclature, is the first pair of *mâchoires auxiliaires* of Savigny, or the anterior *mâchoires* or foot jaws of most authors

These, in the adult Brachyura, are still more embryonic in appearance. In *Maia* and *Cancer* they are very reduced in size and apparent importance (Pl III fig 27), but in some less highly developed types, such as the Amphipoda and Isopoda, where they are generally recognized under the name of *maxillipeds* (Pl III fig 28), they assume a more important feature, and bear a not very distant resemblance to the typical form from which they are supposed to depart In *Nebalia* they closely resemble the posteriorly succeeding pairs of limbs but in this genus the whole of these gradually degenerate to the embryonic condition as they recede from this point

In the larval or zoea stage of Crustacea they are wanting in the higher forms

These three pairs of limbs appear to me to offer an interesting and valuable example of the manner in which any great changes in the variation of the structure of an animal takes place The crowding together so to speak of the three posterior somites of the cephalon, so as to bring, as much as possible, the several pairs of appendages within the limits of the oral region, so crushes them in their position, that their usefulness as separate organs must be much impeded It would therefore appear that the crowding of appendages together interferes with and arrests the progress of their development, while they are best suited to exist under the altered conditions where they are the least inconvenient That they are of little or no importance in the economy of the animal can, I think, be demonstrated in the habits of their life—a circumstance which, I think, can be shown in the slight variation of their structure in the adult stage from that of the larval form, to depart in the anterior members towards the mandibular form, and posteriorly to put on conditions most consonant with the usefulness of the succeeding appendage, that is, while the anterior ones feebly approximate the mandibular form, the posterior have attached to them parts resembling immature branchial organs.

These seven pairs of appendages are all that belong to the cephalon or head; and it appears to me that, however closely any of those that succeed may be associated with them in functional purposes, they are homologically distinct, and, as members of separate portions of the body, they should be named and distinguished in a scientific nomenclature more in accordance with their homological relationship than with their functional power

The next pair of appendages is the first that belongs to the pereion or thorax in the Crustacean type of animals. It is the eighth pair in posterior rotation, but is generally named by authors according to its relation to the mouth It is the *pemptognathe* of Milne-Edwards's more recent nomenclature, the second pair of *mâchoires auxiliaires* of Savigny, and the second pair of *maxillipeds* or foot-jaws of most carcinologists It is the fourth *siagnopodes* according to Professor Westwood's suggestion, and the first pair of *gnathopoda* of the 'History of British Sessile-eyed Crustacea,' according to the nomenclature of the author of this report

This multiplication of names for a single appendage, signifying, as they severally do, various affinities, is by no means flattering to the students of Crustacea, but, to a large extent, it occurs from the circumstance that while one anatomist has contemplated the animal in the adult and higher concentrated forms, others have contemplated it in the more imperfect types It is therefore the object in this report to bring together these several and various discrepancies, and demonstrate the relationship of parts through their various degrees of growth and change, and retain by one fixed name the same part however it may vary in structure or functional conditions through all stages of variation in Crustacean life.

In Crustacea the eighth pair of appendages in the structure of the animal is the first pair that belongs to the body. In the Brachyura it exists in the same type as is found in the zoea or larva form (fig 29), from which it varies only in the more robust character of some of the joints of which it is constructed (Pl III fig 30). In this state it varies in form and degree only within a limited range, gradually becoming more pediform in character as we examine it through the Macrura (Pl III fig. 31) in the descending order until we reach *Squilla* (Pl III fig 32), where we find it developed as a large and important organ that gives a decided and distinguishing feature to the animal. Through this genus we are led to the Edriophthalmia (Pl. III. fig. 33), among which we find that in the Amphipoda it is formed on the same type as in *Squilla*, but gradually approaching in its general characteristics and appearance those of the succeeding pairs of legs, until in the Isopoda it is in most families uniform with them.

Thus we see that not only in their relation to the body of the animal, but also in their most general appearance and affinities they are part of the same system of appendages as those posterior to them, and that their relation to those anterior arises from that crowding together of parts in the higher types of Crustacea that forces an abnormal form as the result.

This pair of appendages, as being the first attached to the "pereion" or body of the animal, may with consistency be called, as it really is, the first pair of *pereiopoda*. But throughout the higher Crustacean forms the first two pairs of appendages are functionally utilized as attendants upon the mouth, and where this is not the case they are formed as organs of prehension, more especially among the male animals. This is exemplified even in those species, as among the terrestrial Isopods, where the outward form is less striking, but the whole appendage is strengthened for grasping purposes

The next or ninth pair of appendages is almost if not universally formed upon the same type as the preceding There is a departure in degree to be found, more pronounced in the Brachyura, in consequence of the appendages crowding so much on one another Thus, while those that experience most the pressure of those that overlap them are precluded from attaining their fully developed forms, the external ones, or they that overlap the preceding, have, in order the more perfectly to fulfil their duties, extended their own surfaces, so as more effectually to protect the oral cavity, as an operculum covering the mouth.

These two pairs are variated so constantly from the other appendages of the pereion that I think it will be found convenient in most cases to designate them by distinguishing names The Reporter has, in the Report on the Amphipoda in 1865 and elsewhere, called them gnathopoda, as feet or appendages connected with the mouth, and I see every reason why this name should be adopted throughout the whole subkingdom, as one better adapted, both functionally and homologically, than those proposed either by Milne-Edwards's latest nomenclature, or the still less correct ones in popular use of previous authors

In the larval form the second gnathopod is less advanced than the first, but in the adult stage it is larger and more efficient. An exception to this exists in *Nebalia*, where all the appendages of the pereion are developed upon an immature or embryonic type These gradually decrease in power and form the more they recede posteriorly All these appendages exhibit the seven joints that are present in the formation of a single limb; and in those instances where there is a decrease in that number, the joint that is wanting is lost at the extremity. This appears to be very general through all the Brachyural and Macrural divisions

In the higher forms both pairs of gnathopoda carry a secondary branch as well as another that has generally been known as the "flabelliform appenage." For these Milne-Edwards has proposed the name of *endognathe* for the primary or internal ramus, *exognathe* for the external or second ramus, and *epignathe* for that which is generally known as the "flabelliform appendage," and *mesognathe* for the fourth But as the representatives or homotypes of these same appendages occur in different grades of Crustacean form, and whenever they do occur they bear the same relation to the limb from which they spring, it would be better that they should consistently be known by their homotypical character, rather than vary their name with every succeeding appendage. Thus the flabelliform appendage invariably springs from the *coxa* or first joint, and is homotypical of the branchial organs in other pairs of limbs; another is invariably connected with the *basos* or second joint, and the third has its origin in the *ischium* or third joint. One or all may be suppressed; but whenever either the one or the other is present it has its origin in its own peculiar joint, and as such should be identified in any scientific nomenclature. I therefore suggest the names of *coxecphysis*, *basecphysis*, and *ischiecphysis* for the several parts*, as branches springing from those joints, in whatever appendage they may be found. Thus the secondary branch that exists attached to the legs in *Phyllosoma* or the young of *Palinurus* is an ischiecphysis; in

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* The name of the joint being compounded with the word ἔκφυσις, *sprout* or *branch*.

Mysis a very similar appendage is the basecphysis, while the branchiæ are, in all cases when present, the homologues of the coxecphysis.

The next five succeeding pairs of appendages are the true legs as they exist in the typical forms of Crustacea, and it is from the general appearance of them that the higher forms are known as Decapoda, or Ten-footed Crustacea. In a scientific point of view the name is incorrect and misleading, for in many of the Macrura and the Edriophthalmia they are twelve or fourteen in number, while in the Anomura the departure of the last two pairs of pereiopoda from the typical form is as great as the two first in many other forms, consequently the name of *Decapoda*, as well as Dana's name of *Tetradecapoda*, is both incorrect and homologically untrue. These five pairs constitute the tenth to the fourteenth pairs of appendages; but as they are limbs attached to the pereion, I have elsewhere suggested that they should be known as pereiopoda. Milne-Edwards, in his nomenclature, has not identified them with any distinguishing name; he merely calls the anterior pair, which is cheliform in many genera, by the name of *bras* (arms), and the rest *pattes* (feet), and it is remarkable that he should identify each one of the seven joints that is present in its construction by a distinguishing term; but the entire member he defines by an unscientific but popular phrase that is inconvenient, as it is found that the prehensile power is not confined to a single pair, but, as in *Astacus* and *Homarus*, is the property of other limbs, while in some, as in *Scyllarus*, it does not exist in any. Carrying this observation into other forms, we find that in certain Amphipoda the great chelate or arm-like organ exists in the fifth pair of pereiopoda, as in *Phronima*. Thus we see that the power of being developed into a grasping forceps or hand exists in each or all the pereiopoda in succession; therefore the term of arm, or *bras*, is inadmissible in a scientific nomenclature. I therefore propose to call these five pairs of appendages the pereiopoda, in accordance with the terms used in the 'History of the British Sessile-eyed Crustacea.'

They invariably consist of seven joints; these are most distinguishable in the Macrura and the lower forms. In the Report on the Sessile-eyed Crustacea, 1855, the author clearly demonstrated the several joints respectively in the Amphipoda. This required no effort on his part to interpret in the Macrura, since in *Homarus*, *Astacus*, and *Palinurus* the general points are very distinguishable, but as we examine higher in the scale of animals, we find that in the Anomura the *coxæ* of the several pairs of legs are gradually becoming absorbed and becoming part of the ventral surface of the body; and this in the Brachyura is carried still further, inasmuch as it is difficult to define how much of the structure is due to the legs and how much to the body, and it is not improbable that the appendages have encroached upon and absorbed the generally more important structure.

The coxa or first joint appears to be essential to the existence of the animal, inasmuch as it is the seat of all the more important organs connected with the vital existence. The auditory and olfactory senses are situated in the coxæ of the antennæ, and all the branchial appendages have their origin in the coxæ of the pereiopoda, while the sexual organs, both male and female, are implanted in the coxæ of the seventh and fifth pairs respectively. The next two joints of the limbs may, and in some of the Stomapoda do, carry appendages attached to them; but none of the joints beyond the ischium are ever so furnished.

The anterior pair is the one most commonly developed in the higher forms into large chelæ or hands. It is the more general in the male than in the female, and I have commonly observed that the female chela generally corresponds more closely with the less-developed chela in males than with the greater. Sometimes the male appendage is developed so monstrously that they appear inconvenient and burdensome, and are occasionally so long that they are useless in an attempt to reach the mouth. Thus in *Homarus* the animal feeds itself with the small posterior pair. In *Gelasimus* no ingenuity on the part of the animal would enable it to reach the mouth with the extremities of the large chelate organ. In the process of feeding they are useful only as holding food while the animal carries it to the mouth with the smaller but more convenient organs. The chela is always formed by the greater or less amount of development that is given to the inferior angle of the distal extremity of the antepenultimate joint. This power of production appears to be dormant in every limb, since we see it occasionally exhibited in all. Thus in *Palinurus* it is rudimentarily present in the posterior pair of pereiopoda, and in the genus *Pagurus* it is developed into a small but efficient organ, by which the animal cleanses out and removes obstructive objects that may have found their way into the branchial chamber, and so fulfils the same duties as those performed by the *flabella* attached to the gnathopoda, and which are wanting in the Anomura.

The fact that the coxae of all the legs attached to the pereion are in some orders absorbed into the sternal plastron, while they are not so in others, offers a ready and safe means by which palaeontologists may determine the order to which a fossil Crustacean might belong by the evidence of a single leg. Thus it will be seen invariably that seven distinct and free joints are visible in the Macrura, while only six are free in the Brachyura, whereas in the Anomura there are six free and one partially so. This evidence might be carried still further, inasmuch as in *Astacus* and *Homarus* the coxae are seen to approximate to each other on the opposite sides closely, while in *Palinurus* they are near anteriorly and broadly separated posteriorly.

The appendages that follow are those that are modified for swimming. When exhibited in the most normal condition, they consist of a long peduncular stalk supporting two oblong leaf-like plates, surrounded by a fringe of small hairs. Sometimes they consist of a series of multiarticulations, as in Amphipoda; sometimes of long cylindrical unarticular branches, as in *Cancer*. In some instances, as in *Squilla*, there is a third branch that springs from the side of the peduncle near the base. This is so membranous in character and ramified in construction that it is evidently formed for the purpose of assisting in aeration of the blood.

The pleopoda are utilized, according to the habits of the animal, for various purposes, and throughout them all their adaptation to propulsion through the water is not only the most constant but also very generally associated with other offices.

In the Isopoda they appear to be the only organs adapted for respiration that the animal possesses. Yet their rapid motion is the only means which they possess of swimming.

In the Amphipoda, it is this latter use alone for which these organs are adapted, while respiration is fulfilled by other means. But here only the anterior three pairs are adapted for swimming purposes, while the posterior three are utilized for leaping when on land, or forcibly dashing through the water. The Isopoda have only the posterior pair so variated, and the Macrura have two pairs, but in this latter order they are more adapted for producing a retrograde motion, darting backwards as they frequently do to avoid unexpected and sudden danger. In the Macrurous forms they are also available for the purpose of retaining connexion with the ova, and supporting the life of the embryo until it is matured. Throughout most of the Macrurous forms the pleopoda fulfil this double purpose in the female.

In the Anomura they are only adapted for swimming in the long-tailed forms; but in Brachyura they are only utilized for the suspension of ova in the female, and never used for swimming except in very young animals, and reduced to two pairs only in the male, where they are interlocked in each other and adapted as organs aiding intromission.

I cannot close this portion of the report without expressing great admiration of the valuable memoir of Milne-Edwards, so frequently quoted in these pages. With the exception of Professor Huxley's Hunterian Lectures, St. George Mivart's Memoir on the Lobster in the 'Popular Science Review,' and a Memoir on the same subject by J. S. Kingsley, recently published in the 'American Naturalist' (Aug. 1876), little has been written on this subject of late years.

It is remarkable that so large and important a class of animals should have been left so long without being anatomically studied, and it is to be hoped that the important part that they must take in the great history of progressive evolution will gradually induce naturalists to give them the attention that their importance deserves.

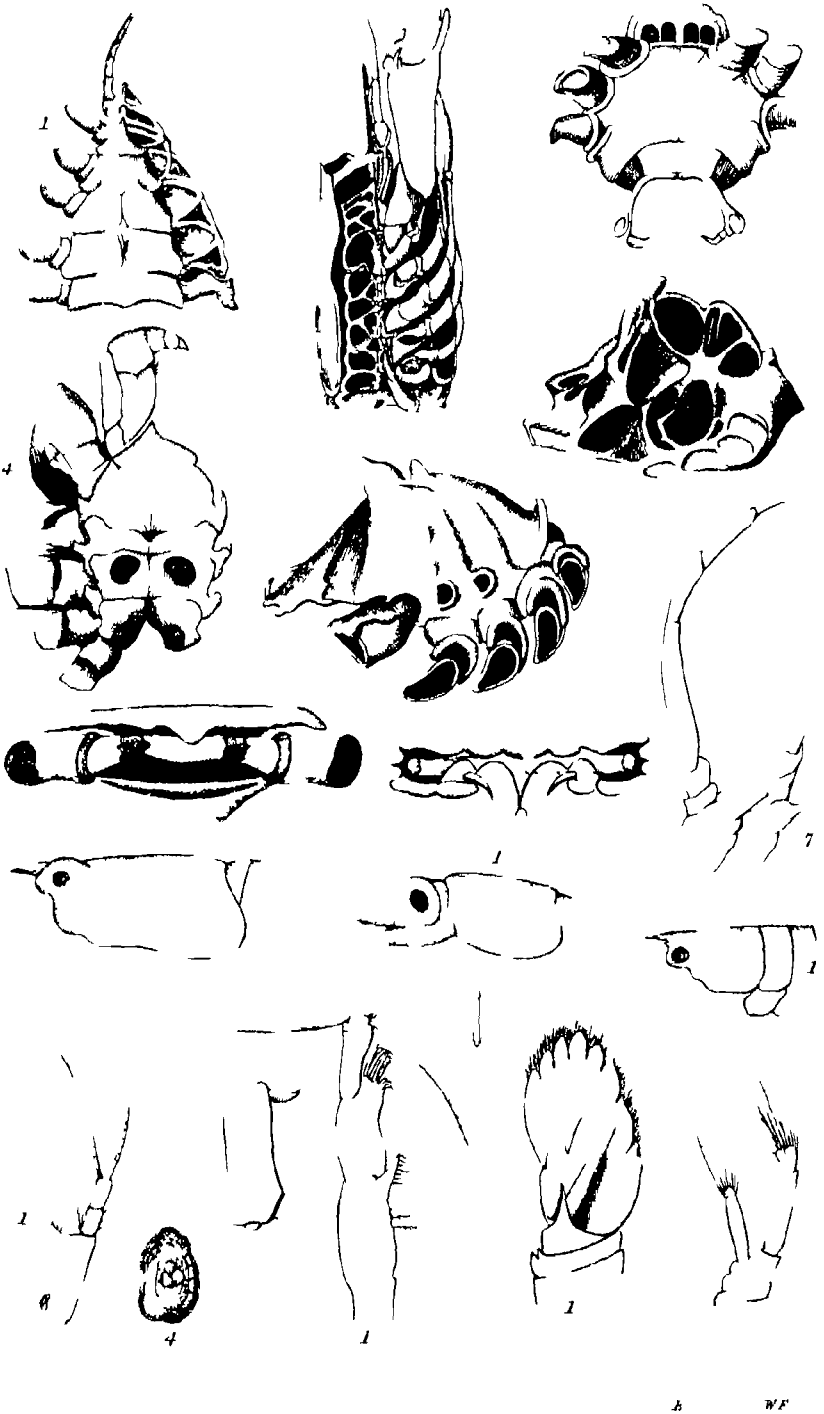
EXPLANATION OF THE PLATES

PLATE II

Fig. 1. Sternum from *Palinurus*.
2. Sternum from *Nephrops*.
3. Sternum from *Lithodes*.
4. Sternum from *Cancer*.
5. Sternum from *Cancer*, lat. ext. aspect. † Dorsal notch.
6. Sternum from *Cancer*, longitudinal section. * Ventral sinus.
7. Spinal processes attached to legs in *Megalopa*.
8. Eyes from *Palinurus*.
9. Eyes from *Cancer*.
10. Eyes from *Alphæus*, adult.
11. Eyes from *Alphæus*, young.
12. Eyes from Amphipoda.
13. Antenna, first, from *Anchistia*.
14. Otolith from same.
15. Antenna, first, *Mysis*, male.
16. Antenna, second, *Scyllarus*.
17. Antenna, second, *Cancer*.
18. Antenna, second, *Pontia*.

PLATE III

19. Mandible from *Nebalia*.
20. Mandible from *Pontia*.
21. Mandible from *Palæmon*.
22. Labium, posterior, from *Palinurus*.
23. Deutognathe from *Cancer*, adult.
24. Deutognathe from *Cancer*, young.
25. Tritognathe from *Cancer*, adult.
26. Tritognathe from *Cancer*, young.
27. Tetartognathe, or maxilliped of authors, *Cancer*.
28. Tetartognathe, or maxilliped, of Amphipod.
29. Gnathopoda from *Cancer*, young.
30. Gnathopoda from *Cancer*, adult.
31. Gnathopoda from Macrura.
32. Gnathopoda from *Squilla*.
33. Gnathopoda from Amphipoda.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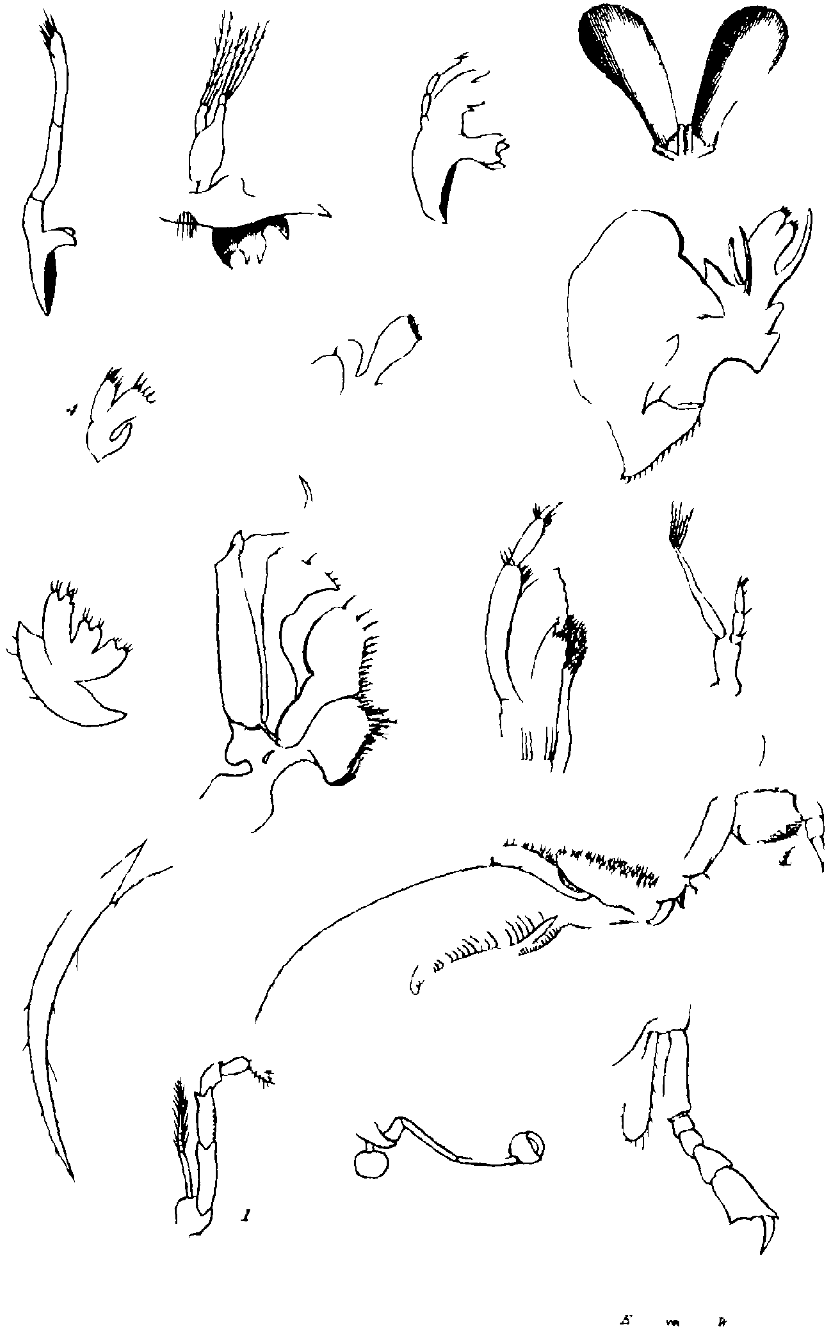

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Second Report of the Committee for investigating the circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England, and the quantity and character of the water supplied to various towns and districts from these formations. The Committee consisting of Professor HULL, Mr BINNEY, Rev H W CROSSKEY, Captain D GALTON, Professor A H. GREEN, Professor HARKNESS, Mr H HOWELL, Mr W MOLYNEUX, Mr G H MORTON, Mr PENGELLY, Professor PRESTWICH, Mr J PLANT, Mr MELLARD READE, Mr C FOX STRANGWAYS, Mr W WHITAKER, *and* Mr C E DE RANCE. *Drawn up by* Mr DE RANCE *(Secretary)*

SINCE the last Meeting of the Association your Committee have continued to distribute largely the circular forms of inquiry, and a large amount of valuable information has been obtained, especially as to the deep wells of Liverpool, Birkenhead, Nottingham, and Birmingham. But in several districts, as in Staffordshire, important information is promised so soon as works now in progress are completed, and the members of your Committee taking charge of those districts have considered it best to defer making a report until they present you with a final one on their particular areas. Your Committee, should they be reappointed, have every hope from promises already received, of completing the trust which you have given them by the next Meeting of the Association.

In the present Report the details of wells in the New Red Sandstone are collected, which yield at Liverpool no less than 7,197 330 gallons daily, at Birkenhead more than 7 millions, at Coventry, Birmingham, and Leamington 4½ millions, at Nottingham nearly 4 million gallons, at Warrington 572,360 gallons, at Stockport 1 073 820 gallons.

The largest yield of one individual well is that at Green Lane, Old Swan, near Liverpool, the average daily yield of which in 1875 amounted to 2,533,050 gallons, and the present maximum of which amounts to no less than 3,243 549 gallons pumped up by three engines, one at least of which is always at work, from a depth of 136 feet.

In regard to the Liverpool wells it appears to be established by the observation of Mr Deacon, the Borough Engineer, to quote the words of his Report, "That the water in the public wells is regularly sinking to a lower level, or that if it be maintained at a constant level, the water capable of being pumped is a continually diminishing quantity." But there is not yet sufficient evidence to prove what balance of absolute quantity of water still remains in the sandstones of the area capable of being drawn on by additional wells.

Amongst the borings of which the details will be found in the present Report, is one at Rampside near Barrow in Furness which reached a depth of no less than 2210 feet from the surface, in a fruitless search for coal. At a depth of 250 feet a spring of water was cut in the Permian Red Sandstone, which yields 13,500 gallons of water daily flowing out at the top of a one-inch pipe, and rising to a height of 12 feet above the surface of the ground.

The rocks beneath the Permian have been proved by this boring to be of Yoredale age, the Coal-measures being absent, as stated would probably be the case by Mr Aveline and other geologists before the boring was carried out.

An interesting feature in this boring is the presence of petroleum-oil in the Yoredale rock near the bottom, which caused the water cut in penetrating this sandstone to be much charged with oil.

Your Committee would wish to call attention to the publication, since the last Meeting, of the sixth and final Report of Her Majesty's Commissioners appointed to inquire into the best means of preventing the pollution of rivers. The volume treats of the Domestic Water Supply of Great Britain, and in it the Commissioners state that the New Red Sandstone Rock constitutes one of the most effective filtering media known, and being at the same time a powerful destroyer of organic matter, the evidence of previous pollution, in water drawn from deep wells in this rock, may be safely ignored, "for being a porous and ferruginous rock it exerts a powerful oxidizing influence upon the dissolved organic matter which percolates through it. To such an extent is this oxidation carried, that in some cases, as in those of the deep-well waters supplying St. Helens and Tranmere, every trace of organic matter is converted into innocuous mineral compounds."

The Commissioners further add that, though the quartz sand constituting the bulk of the New Red Sandstone is usually cemented together by carbonate or sulphate of lime, the hardness of the water is generally moderate, and of a nature that can be softened by lime, according to Dr. Clark's method, and that the 'unpolluted waters drawn from deep wells in the New Red Sandstone are almost invariably clear, sparkling, and palatable, and are amongst the best and most wholesome waters for domestic supply in Great Britain. They contain, as a rule, but a moderate amount of saline impurity, and either none or but the merest traces of organic impurity. There is every reason to believe that a vast quantity of hitherto unutilized water of most excellent quality is to be had at moderate expense from this very extensive geological formation.'

This area is certainly not less than ten thousand square miles in extent in England and Wales, with an average rainfall of 30 inches, of which certainly never less than 10 inches per annum percolates into the ground, which would give an absorption of water amounting to no less than one hundred and forty-three millions three hundred and thirty-six thousand gallons per square mile per annum, which, on an available area of ten thousand square miles, gives an annual absorption of nearly a billion and a half of gallons in England and Wales.

How small a proportion the enormous quantities pumped at various stations (as exemplified in this and the previous Report) bear to the available resources, will be at once apparent. The abundant balance left will, we trust, ere long be made available for those towns and country populations in the Midland Counties now suffering all the ills so prolifically springing from a polluted water supply.

MIDLAND COUNTIES.

Name of Member of Committee asking for information, Rev. Henry W. Crosskey.

Name of Individual or Company applied to:—

Waterworks, Coventry.

1 One 100 ft. deep, one 75 ft. deep, and one 300 feet from surface. **2** 250 ft. **3** 10 ft., 4 ft. diameter, 200 feet, from 2 ft. to 6 in. **4** 14 feet, difference 12 hours. **5** 800,000. **6** Yes, diminished slightly. **7** Yes, in a few hours. **8** No. **9** Red Sandstone and clay. **13** No. **14** Not aware of any except at Leamington. **15** No.

Birmingham Corporation.

1 Aston, *juxta* Birmingham. **2** 295 ft. **3** 120 ft., diameter 10 ft., 407 ft., 18 in. bore-hole. **4.** Overflows 10 ft. above surface, 100 ft., pump night and day. **5.** 3 million gallons. **6** Not observed to have altered. **7.** Not observed.

		Grains per gallon
8 Total solids		12·88
Volatile combustible matter		0·84
Chloride of lime		0·01
Nitric acid		0·00
Hardness before boiling	9°·3	

9 28 ft of iron tube through top soil and drift gravel, then rest all sandstone with marl and partings and some fine conglomerate, finish at bottom of hole in 25 ft thick of marl **10** Yes **11** Yes **12** No **13** No **14** None nearer than Cannock **15** No

Name of Member of Committee asking for information, T Mellard Reade
Name of Individual or Company applied to —

Leamington Local Board per Mr Bright

1 North east portion of Leamington **2** 205 ft **3** 80 ft deep, 8 ft diameter 234 ft deep, 18 in diameter **4** Normal level 20 ft below surface **5** 750 000 galls per day **6** Works not yet completed **7** Top of water is 20 ft above river Leam **8** Analysis attached, water remarkably pure and soft, whereas surface wells contain very hard water

Analysis of water from the new bore hole by Dr Horace Swete taken from a depth of 200 ft from surface Water very clear almost as clean as distilled water —the smallest point being easily read at a depth of 2 ft Temperature at well, 50° Fahrenheit, requires no filtration

		Grains per gallon
Total solids		20·0
Chlorides		1·3
Sulphates—very sparingly		
Nitrate a trace		
Faint trace of iron		
Temporary hardness	5·5	
Permanent ,,	6·5	
	12·0	

	Parts per million
Free ammonia	·000
Albuminoidal ammonia	·020

This water is an extremely pure specimen even for a deep well, and requires no filtration It contains less than *one tenth* of the amount of organic matter than the present town supply and is not only a softer water for domestic purposes, but the deposition of carbonates causing incrustation in boilers is considerably less in quantity

February 2nd 1875 HORACE SWETE, M D, *Analyst*

9 Map of strata previously sent, consisting of sandstone of various thickness divided by marls **10** Yes **11** Yes **12** Not within a mile, where one is known south of Borough, and another two miles *west* **13** No **14** Yes in the valley half a mile south **15** Yes the first experimental boring was discontinued in consequence of finding, under the saliferous marls, very salt water, one layer of this marl being more than 100 ft thick

Name of Member of Committee asking for information, C Tylden Wright
Name of Individual or Company applied to —

The Manager Nottingham Waterworks

1 Bestwood pumping Station, near Nottingham **3** Depth of shaft 64 yards, size 10 ft × 10 ft, two tunnels are driven out from the bottom about 50 yards **5** Maximum quantity pumped for 24 hours 3,772 800 galls minimum quantity 3,456,000 galls **9** Pebble beds of the New Red Sandstone

1 Worksop **3** Bore-hole 4 inches in diameter, depth 300 ft **5** Pumping in 1875, 40 gallons per minute

Shire Oaks Colliery, Worksop

1 Shire Oaks Colliery, Worksop **3** 3 shafts, 12 ft diameter

		Galls	Depth
5 Water per hour	Yellow limestone	400	17 yds
	White "	350	25 "
	Dark "	50	38 "

9 Permian marls and magnesian limestones, the principal feeder of water occurs in a soft coarse sandstone lying on the bottom of the magnesian limestone

Papplewick Colliery, through Mr W. F. Webb of Newstead Abbey

1 Papplewick, near Annesley **3** 330 yards shaft **5** At 9 yds a little water, at 44 yds 7 in 18 galls per minute tubbed out, at 60 yds 50 galls, below this only an increase of 5 or 6 galls **9** Drift

		yds	ft
Magnesian limestone	at	9	1
Black shale (coal-measures)	"	36	2
First coal		46	0
Plant impressions	"	135	0

13 At 126 yds 2 ft a small salt spring 3 galls per minute

Mr Robert Stevenson, through Mr W. F. Webb, of Newstead Abbey

1 Newstead Colliery **3** Bore hole at Colliery gives off 2044 galls of water per minute New Red Sandstone, near outcrop of the formation

Mr W. F. Webb, Newstead Abbey

1 Blidworth

			yds	
3 Depth of well at the Hut			42	In clay, with limestone fragments and gravel
"	"	Gurnall's	3	
"	"	Needham's	6	
"	"	Fosters	13	
"	Town-pump well		6	
"	School well		5	
"	Well at G. Clarke's		50	In Sandstone
"	"	Waters	10	
"	"	Hutchinson's	40	
"	"	Wilson's	39	
"	"	Herbert's	6	
"	Town well		30	
"	Well at Hairs		0	
"	"	G. Johnson's	27	
"	"	Dixon's	26	
"	"	Mount Pleasant	31	
"	"	Cresswell's	28	
"	"	New Lane	31	
"	"	Lucas Cross Lane	34	
"	"	Blidworth Bottom	8	
"	"	Long Dale	26	
"	Wells at Fishpool		6 25	

9 Drift-gravel and clay, red sandstone, the water occurs immediately after passing through a seam of conglomerate 3 inches thick At Fishpool is a spring, which, after 20 years cessation, commenced running during the dry summer of 1868, and then stopped, but recommenced in the summer of 1874 **10** Yes, which supply the shallower of the above wells

Name of Member of Committee asking for information, W. Whitaker.
Name of Individual or Company applied to —

Staffordshire Potteries Waterworks, Hanley

1. North Staffordshire, 4 miles S E from railway-station, Stoke-upon-Trent (1 in

Ordnance sheet, 72 N W) **2** 615 ft **3** Shaft 145 ft deep, 12 ft diameter, bore hole 500 ft deep, 24 in diameter **4** The level of water in this case is kept down nearly to bottom of *shaft*, but the water has been found to fill 900 cub yards of standage drift and rise about 20 ft up shaft in 24 hours **5** [illegible]00,000 galls **6** The seasons affect this shaft very little the feeders have been permanent during the past 5 years, but *less* than when the shaft was *put* down (bore hole in hand at present) **7** No **8** Water of good quality about 9° hardness **9** New Red Sandstone (with bands of marl of considerable thickness) cover about 20 ft If a section of the shaft and bore hole would be of service I should be glad to supply the same **10** About 1 mile N E there are several copious springs and apparently quite unaffected by the above sinking **11** No surface-spring near well **12** There are several *faults* in the immediate locality A large *fault* running about *N E*, and about 1 mile north of *this* shaft, supposed to be the *southern limits* of the N Staffordshire coal-field, but borings just completed to the *south* have proved coal at a depth of *205 yards* **13** None **14** None to my knowledge **15** The above well is the only one in the neighbourhood sunk for the purposes of water supply

Messrs Mather and Platt

1 Messrs Lonsdale and Adshead, Macclesfield **3** 12 inch bore, 94 ft deep **5** 66,240 galls

LANCASHIRE AND CHESHIRE

Name of Member of Committee asking for information, G H Morton
Name of Individual or Company applied to —

Mr George F Deacon, C E, Municipal Offices Dale Street

1 Litherland Road, Bootle, near Liverpool **2** 60 feet **3** Depth of shaft 108 ft, oval 12 0 × 9 0 * **4.** Pumping continuously except when stopped for repairs During a stoppage from [illegible]0th Jan to Feb 18, 1876, the water rose 11 ft above Ord datum, or 56 ft above the bottom of the well **5** Average for 1875, 1,[illegible]90,701 galls present maximum 1,433,720 galls **6** See reports herewith **7** See No 4 Effect of local rains not traced

8 Copy of Analyst's last report

Total solid Matter in Solution	Organic Carbon	Organic Nitrogen	Ammonia	Nitrogen as Nitrites and Nitrates	Total combined Nitrogen	Chlorine	Total Hardness	Suspended Matter
gr 36 6	gr 181	gr 055	gr 002	gr 345	gr 401	gr 3 6	23¼	Clear and bright

9 P 2, drift about 12 ft (pebble beds and "Lower soft Bunter Sandstone") **10.** No **11** The well is lined with brickwork in cement down to the hard rock **12.** Yes **13** No **14.** No

1 Green Lane, Old Swan, near Liverpool **2** 136 ft **3** Shaft 10 ft diam, depth 185 ft, 1 bore hole 9 in diam for 173 ft 9 in, and 6 in diam for 25 ft 10 in from bottom of shaft, 1 bore-hole 24 in diam for 12 ft, and 18 in diam for 298 ft **4** There are 3 engines, and the whole are never stopped at one time Average for 1875, 2,533,050 galls, present maximum 3,243 519 galls **6** It has diminished (see reports herewith) **7** Effect of local rains has never been directly traced

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* There are altogether about 16 bore holes in the lodges connected with this well They were sunk many years ago, and records have not been preserved of the details The principal bore hole is 6 in diameter at the top and its depth from the surface is about 650 ft

8. Copy of Analyst's last report

Total solid Matter in Solution	Organic Carbon	Organic Nitrogen	Ammonia	Nitrogen as Nitrites and Nitrates	Total combined Nitrogen	Chlorine	Total Hardness	Suspended Matter
gr 28	gr ·085	gr 06	gr 003	gr 345	gr 408	gr 2 72	° 20	Clear and bright

9 Rock F 2 ("Bunter Pebble-beds"), cover of drift and clay 15 to 20 ft **10.** No **11.** There are none. **12.** Yes **13** No **14** No **15** No

1. Dudlow Lane, Wavertree, near Liverpool **2.** 200 ft **3** Depth of well 247 ft , shaft oval, 12′ 0″ × 9′ 0″ , depth from surface to bottom of bore-hole 430 ft , diameter of bore-hole 18 in **4.** Pumping continuously except when stopped for repairs Stoppage from 5th to 30th Nov. 1875, water rose to 95 ft from bottom of well **5.** Average for 1875, 1,103,307 galls , present maximum 1,329,107 galls. **6** See printed reports herewith. **7.** See No. 4 , effect of local rains not directly traced

8 Copy of Analyst's last report

Total solid Matter in Solution	Organic Carbon	Organic Nitrogen	Ammonia	Nitrogen as Nitrites and Nitrates	Total combined Nitrogen	Chlorine	Total Hardness	Suspended Matter
gr 18	gr ·091	gr 031	gr 003	gr 368	gr 402	gr 2 87	° 8	Clear and bright.

9 F 2 ("Bunter Pebble-beds") rock nearly to the surface, only thin cover of drift. **10** No **11** There are none. **12.** No **13.** No. **14.** No.

1. Lodge Lane, Toxteth Park, Liverpool **2** 180 feet **3.** Depth of shaft 210 ft , oval, 12′ 0″ × 10′ 0″, depth from surface to bottom of bore-hole 454 ft., diameter of bore-hole 6″ for 180 ft , 4″ for 55 ft **4** Pumping continuously, except when stopped for repairs In a stoppage from the 3rd to the 13th April the water rose to 50 ft 6 in from bottom of well **5** Average for 1875, 821,182 galls , present maximum 876,428 galls **6** See printed reports herewith. **7.** See No. 4 ; effect of local rains not traced

8. Copy of Analyst's last report.

Total solid Matter in Solution	Organic Carbon	Organic Nitrogen	Ammonia	Nitrogen as Nitrites and Nitrates	Total combined Nitrogen	Chlorine	Total Hardness	Suspended Matter
gr 35	gr ·051	gr ·011	gr 003	gr 276	gr 29	gr. 2 72	° 23½	Clear and bright.

9. F 2 ("Bunter Pebble-beds") Cover of drift about 20 ft. **10.** No. **11.** There are none. **12.** No. **13** No. **14** No.

Messrs. Mather and Platt.

1. Messrs. Roberts and Robinson, Liverpool. **3.** 18-in bore, 463 ft. deep. **5.** 1,440,000 galls. **9.** New Red Sandstone.

Name of Member of Committee asking for information, T. Mellard Reade.
Name of Individual or Company applied to —

Ormskirk Local Board.

1. The well is situate within a short distance from the town of Ormskirk, on the N.E. side and near to Bath Wood. 2. 120·1 ft. above Ordnance datum. 3. From surface to bottom of well 60 ft. deep, 7 ft. diameter. There is no bore hole in the well. 4. Before pumping the water rises to the surface of well; after pumping the water stands 2 ft. deep at bottom of well. Ordinary level restored in 2 hours after pumping. 5. 232,000 galls. 6. The water level varies slightly in summer and winter, but has not diminished during the last 10 years. 7. The ordinary level is affected by local rains within 24 hours afterwards. 8. Analysis of the Ormskirk water by Dr. Brett, of Liverpool. This water when left to stand is perfectly colourless, devoid of odour, and pleasant to the taste; its composition is as follows, the amount of ingredients being calculated to the imperial gallon:—

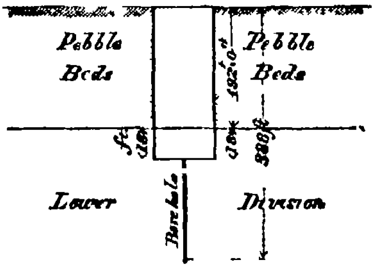
	grains
Chloride of sodium or common salt	3·20
Sulphate of lime, or gypsum	1·92
Carbonate of lime	1·04
Carbonate of magnesia	0·40
Oxide of iron with a little silica	0·12
Total	6·68

9. The strata are, first marl 11 ft., sand 7 ft., the remainder is New Red Sandstone. 10. Yes. 11. No. 12. Yes, especially a very large fault on the west side of well. 13. No. 14. No. 15. No.

Name of Member of Committee asking for information, George H. Morton.
Name of Individual or Company applied to —

St. Helen's Waterworks.

1. Eccleston Hill, adjoining turnpike, and at the sandstone-quarry, marked 260 ft. above Ordnance datum (see Ordnance sheets). 2. 260 ft. 3. Depth 70 yards, diameter 10 ft.; depth from surface to bottom of bore-hole 388 ft. 4. As the pumps never cease pumping it is difficult to say; meanwhile the water is practically kept down to one level. 5. 640,000 galls. per day of 24 hours. 6. The yield varies at different seasons, but to what extent it is difficult to say; the water has diminished during the past 10 years. 7. Yes, but after a dry summer it takes 8 or 10 weeks before the 1 or 2 extra hours out of the 24 can be resumed by the extra engine. The water level in wells stands below adjoining streams. 8. We have no analysis; the water is of very excellent quality. 9. No drift. The wells or shafts are sunk in the New Red Sandstone formation, through the middle or pebble-beds division of the Bunter, and to a depth from the surface of about 18 ft. into the lower division, 70 yards in all. Thus,



After boring 60 ft. deep, no water-yielding strata found—that is, 60 ft. below bottom of well, and in lower formation.

10. No drift. 11. No. 12. Cannot speak of those (if any) with certainty, none proved. 13. No. 14. No. 15. No.

Name of Member of Committee asking for information, Mr. T. Mellard Reade.

Name of Individual or Company applied to.—

Messrs Mather and Platt.

1. Seedley, near Manchester **3** 102'×87", 382'×18", 354'×18", 167'×18". **5.** 750,000 galls. from the three holes* **9.** Red Sandstone with bands of raddle.

1. Chester Street, Oxford Street, Manchester **3** 70'×4', 536'×15". **5** 570,000 galls.

1. Messrs Bayley and Craven, Manchester. **3.** 18 in diameter, 454 ft in depth. **5** 618,000 galls **9** New Red Sandstone

1 Messrs Aitken Brothers, Manchester. **3.** 18-in bore, depth 378 ft **5.** 800,000 galls **9** New Red Sandstone

1 Messrs William Sumner, Manchester **3** Bore 12 in diameter, 189 ft. in depth **5** 46,080 galls **9.** New Red Sandstone

1 Messrs Rylands and Sons, Manchester **3.** 12-in. bore, 312 ft in depth. **5** 90,720 galls **9** New Red Sandstone

1 Messrs B D Brookes, Manchester. **3** 12-inch bore, 250 ft. in depth. **5.** 86,400 galls **9.** New Red Sandstone

1 London and Manchester Plate Glass Company, St Helen's. **3.** 9-inch bore, depth 348 ft **5** 48,000 galls **9.** New Red Sandstone

1. Messrs A and J Stott, Flixton, Manchester **3.** 12-inch bore, 284 ft in depth **5.** 317,520 galls **9** New Red Sandstone.

1 Messrs Chadwick and Taylor, Higher Broughton, Manchester **3** 75'×10', 671'×15" **5** 800,000 **9** See Section

1. The Convalescent Hospital, Cheadle **3** 12 in. diameter, 145 ft. in depth. **5.** 55,200 galls **9.** New Red Sandstone

1. Messrs Ermen and Roby, Patricroft **3.** 18 in diameter, 315 ft. deep. **5.** 100,800 galls **9.** New Red Sandstone

1. Salford Ironworks, Manchester. **3** 18 in diameter, 212 ft deep. **5.** 50,000 galls. **9** New Red Sandstone

1. Messrs Thoms, Chadwick, Salford **3** 12-inch bore, 432 ft deep. **5.** 50,000 galls. **9.** New Red Sandstone

1. Messrs J J M Worrall, Salford **3** 18 in diameter, depth 400 ft. **5.** 480,000 galls **9.** New Red Sandstone

1 Messrs Roberts, Dale & Co, Cornbrook. **3.** 9-inch bore, 178 ft. deep, **5.** 30,000 galls **9** New Red Sandstone.

Name of Member of Committee asking for information, George H. Morton.
Name of Individual or Company applied to —

Birkenhead Commissioners, per Mr. W. T. Callow, Water Engineer.

1 Flaybrick well, Birkenhead **2** 176 ft **3** Shaft 205 ft., 16 ft.×8 ft; the bore-hole 322 ft, 18 in wide, the bore-hole 773 ft, 18 in, Aug. 11, 1876† **4** 156 ft from the surface **5** Usually 1½ million galls in 13 hours, 2 or 3 millions have sometimes been obtained by continuous pumping for 24 hours. **6.** No. **7.** A little additional in wet seasons. **8** Result of analysis expressed in parts per 100,000.—

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* The three bore-holes are all in the same well, and the water rises into well, and is pumped up to the surface

† In progress and will probably be 800 ft., the deepest in the neighbourhood of Liverpool

Total solid matter in solution	15
Organic carbon	074
Organic nitrogen	066
Ammonia	002
Nitrogen as nitrites and nitrates	345
Total combined nitrogen	413
Chlorine	3 7
Hardness, total	4½°
Suspended matter clear and bright	

9 No drift base of Keuper Sandstone, upper soft Bunter Sandstone, Pebble-beds **10** No drift **11** There are none **12** There is a fault close to the well, with a throw of about 70 ft **13** No **14** No **15** No

George H Morton, Birkenhead Commissioners, per Mr W T Callow

1 *Spring Hill, Claughton, Birkenhead* **2** 125 ft **3** *Shaft 95 ft deep (2 shafts* 7 ft diameter) bore hole [illegible] ft from surface **4** 115 ft from the surface **5** 5 million galls per week are obtained by pumping night and day **6** Does not vary, has diminished 20 ft since 18[illegible]8 **7** No **8** Result of analysis expressed in parts per 100,000 —

Total solid matter in solution	21
Organic carbon	110
Organic nitrogen	0[illegible]2
Ammonia	·0[illegible]2
Nitrogen as nitrites and nitrates	25[illegible]
Total combined nitrogen	317
Chlorine	3 1
Total hardness	10¼°
Suspended matter clear and bright	

9 No drift base of Keuper Sandstone, Upper soft Bunter Sandstone **10** No drift **11** There are none **12** No, not very near **13** No **14** No **15** No

Wirrell Waterworks Company Prenton, Birkenhead

1 Prenton valley 3 miles S W of Birkenhead **2** 80 ft **3** 90 ft, diameter about 12 ft, bore 29[illegible] ft, diameter 18 in **4** 68 ft, fills rapidly pumping **5** About 2 000 000 galls **6** No **7** No **8** Very pure and good **9** Boulder-clay about 10 ft, the rest Upper Bunter but the bore-hole chiefly in the pebble-beds **10** No **12** Only of the ordinary kind **13** No **14** No **15** No

1 Wirrell Waterworks, *Oxton near Birkenhead* **3** 22 0 × 4, 369 × 15 **5** 750,000 galls **9** White and Red Sandstone, chiefly red

Tranmere Local Board, per Mr W A Richardson, C E

1 Happy Valley, western side of the township of Tranmere **2** 89 ft 15 in, **3** 128 ft, 9 ft. diameter of shaft, bore-hole 250 ft, 9 6, 4 in, and 130 ft 15 in from *bottom* of well, 378 and 318 ft from surface **4** 78 ft 8 in below surface **5** 720,000 galls **6** No, it has diminished 9 ft 6 in in 10 years but only 2 ft 1 in during the last 8 years **7** No, 23 ft 2 in above sea level **8** Clear, pure, and tasteless, about 8 75 degrees of hardness, analysis —

	Grains per gall
Free ammonia	0 0035
Ammonia derived from organic matter	0 0018
Organic matter, exclusive of nitrogen	0 0180
Carbonate of lime and magnesia	5 8770
Carbonate of soda	1 6960
Sulphate of lime	3 5720
Nitrate of magnesia	0 9040
Chloride of sodium	3 8440
Silicic acid, a mere trace	
	15 9763

9 15 ft of drift, no clay Upper soft Bunter Sandstone **10** No **11** There are none **12** One about 150 yards to the east of well. **13.** No **14.** No. **15.** No

Wallasey Local Board

1 Township of Seacombe, parish of Wallasey, county of Chester, between the Great Float, Birkenhead, and River Mersey **2** About 20 ft **3** 90 ft, 246 ft, 12 in and 8 in diameters **4** If at rest many hours, about 16 ft *before*, and *after* pumping about 50 ft from surface **5** Present machinery has pumped about ¾ million galls per diem, it is estimated that at least twice can be by additional boring, &c (in hand) **6** Does not vary much, diminution, during time named, due to increased pumping Cannot say otherwise, as engine cannot be stopped long enough to test the question **7** Not perceptibly Level when at rest would stand a few feet above mean high water level **8** Have not an analysis at hand, water about 6° of hardness (Clark's test), water very good and clear **9** Section sent herewith —

		ft
Red marl	to	78
Sand and marl	,,	87
Marl	,,	93
Clay and sands	,,	96
White rock	,,	108
Red rock	,,	164
Grey rock	,,	176
Hard red rock	,,	198
Soft red rock	,,	240
Bottom of bore-hole	at	300

11 Yes **12** It is believed so **13** No **14** Not aware of any **15** Not aware of any deep ones

Mr William Inman, J P

1 Upton, 4 miles W of Birkenhead **2** About 100 ft **3** 173 ft, diameter about 8 ft, bore 278 ft diameter, and 6 in wide **4** About 100 ft above Ordnance datum **5** Not known **6** Not known **7** Not known **8** Very good **9** All red marl of Keuper **10** No **12** One about a mile E of the well, which brings the Upper Bunter and red marl in contact **14** No

Name of Member of Committee asking for information, T Mellard Reade.
Name of Individual or Company applied to —

Messrs N Mathieson & Co, Widnes

1. Our own, No 1 well, at N E end of works, Widnes **2.** 10 ft **3** 4 ft 6 in diameter × 30 ft deep bore-hole 386 ft from surface, 6 in diameter Before, about 6 ft from surface after 5 hours, about 25 ft from surface **5** About 2000 galls per day of 12 hours **6** Not being used No means of testing **7** No. **8** No analysis taken, moderately good

		ft	in
9.	Marsh clay	7	0
	Quicksand	23	0
	Brown clay	10	0
	Quicksand	6	0
	Boulder-clay	90	10
	Red rock	275	2

10. Little, from quicksands **11** Not entirely **12** Boring in the fault. **13** No. **14.** No **15.** None

Messrs Sullivan & Co, British Alkali Works, Widnes

1. We have two wells, Nos 1 and 2, at these works, they are about 500 yards apart, and each about 300 yards from the River Mersey **2** No 1 well is about 25 ft, and No 2 well about 15 ft above the mean sea-level **3** No 1 well, for a depth of 27 ft from the surface is 6 ft diameter, for a further depth of 31 ft. is 5 ft diameter, equal 58 ft total depth of well from surface, the bore-hole is 306 ft. deep from surface × 4 in diameter No 2 well, for a depth of 38 ft from the surface is 10 ft diameter, for a further depth of 22 ft is 8 ft diameter, equal to 60 ft total depth from surface, the bore hole is 400 ft deep from surface × 14 in diameter **4** No 1 well water stands 10 ft from surface before pumping, and takes 4 to 5 hours to rise to the same level again after pumping No 2 well water stands 6 ft from surface before pumping and takes 1 to 2 hours to rise to the same level again after pumping **5** No 1 well about 70,000 galls per 12 hours No 2 well about 100 000 galls per 12 hours **6** At No 1 well the yield is less during the summer months than the winter months, and the yield is much less all the year round than it was when the well was first sunk some 7 years ago No 2 well has only been finished some six months, no variation in the yield has yet been perceived **7** Not when the water from the quicksand is kept out of the well In No 1 well the water level is about 15 ft, and in No 2 well about [illegible] ft above the mean water level of the River Mersey, which is the nearest stream **8** The waters from both wells yield about 24 grains of solid matter per gallon when evaporated down chiefly salts of calcium **9** No 1 well 2 ft of soil 36 ft of strong brown clay, 17 ft of quicksand, 2 ft 9 in of sand and pebbles, 61 ft of strong brown clay 5 ft of quicksand and pebbles, remainder Red Sandstone No 2 well 2 ft of soil 28 ft of strong brown clay, 21 ft of quicksand, 61 ft of soft clay remainder Red Sandstone **10** No the quicksands passed through of course yield water **11** Yes the water from quicksands is kept out but can be turned in at pleasure **12** No **13** No **14** No **15** We are not aware of any

The Sankey White Lead Company

1 On the works of the Sankey White Lead Company Limited, Sankey Bridge, near Warrington **2** About 25 ft **3** 33 ft 4 in from surface to bottom of well, 5 ft 6 in diameter, 100 ft from surface to bottom of bore 8 in diameter **4** 3 ft 6 in from surface height to which the water rises rose 23 ft 4 in in 4 hours **5** 40 galls per minute **6** No perceptible variation only at work from 5 to 6 years **7** No observations **8** No accurate analysis **9** No rock was met with Section as follows —

	ft	in	
Soil	1	6	Wet
Sand and gravel	6	6	
Clay with boulders	45	0	Absolutely dry
Sand and gravel	2	0	Spring of 15 galls per minute
Clay as above	25	0	
Sand and gravel	5	0	A little increase of water, drift coal
Clay with thin bands of gravel	15	0	Bore ends in a bed of clean gravel, about 3 ft thick, the last 15 ft increased supply to 40 galls per minute
	100	0	

11 All surface-springs kept out **12** We know of none **13** No **14** Not very near **15** In Warrington bores have been abandoned from this cause

Messrs Mather and Platt

1 Warrington Wire Company, Warrington **3** 18-inch bore, 212 ft deep **5** 63,300 galls **9** New Red Sandstone

1 Messrs Roberts, Dale and Co, Warrington **3** 9-inch bore, 225 ft in depth **5** 28 000 galls **9** New Red Sandstone

1 Messrs Jas Owen and Co, Winwick, Warrington **3** 18 in diameter, 212 ft. deep **5** 461,000 galls **9** New Red Sandstone

Wm Wood Blake, Esq, Warrington House, Northwich, Cheshire

1 Alsager boring, within 300 yards of Alsager Railway Station **2** 310 ft. **3** Tapped water at a depth of 553 ft in a 3-inch bore-hole **4** The water rises to the surface, supplying first a 4-inch bore, then a 5-inch bore at the top, when a 3-inch iron tube is screwed on the 5-inch tube, the water rises to 10 or 12 ft above the surface **8** Has been analyzed, and is very pure and soft, and suitable for brewing purposes. **9.** Passed through red marl and grey rock, with thin bed of gypsum, to the red sandstone rock, when the water was met with, continued the boring in the red sandstone to a depth of nearly 1000 ft, but the water was not increased thereby **10** No **11** This is a report of boring operations **12.** Within 1 mile **13.** No **14.** Within 2 miles. **15.** No Within ½ a mile of the above boring there is a large mere, called "Alsager Mere," 11 acres in extent, with neither an inlet or outlet on the surface, the water of which is very clear and pure. This lake ebbs and flows, rising sometimes even in very dry seasons

Messrs Mather and Platt.

1. Stockport Waterworks, Wilmston. **3** 12-inch bore, 170 ft deep **5** 54,700 galls **9.** New Red Sandstone.

1. Messrs Charles Marsland, Stockport. **3** 12-inch bore, 182 ft deep **5** 30,560 galls **9.** New Red Sandstone.

1. Messrs R Sykes and Co, Stockport. **3** 18 in. diameter, 42 4ft in depth. **5.** 806,400 galls

1 Messrs J E & W. Christy, Stockport **3** Diameter 12 in, depth 228 ft. **5.** 3,200 galls **9** New Red Sandstone

1 Messrs. S. & T Carrington, Stockport. **3** Diameter of bore 12 in, depth 190 ft **5** 50,000 **8** New Red Sandstone

1. Messrs Robert Orme, Stockport **3** 12 inches diameter of bore, depth 192 ft. **5.** 24,960 galls

1. Messrs Bayley & Co, Stockport **3** 18-inch bore, 274 ft deep. **5.** 30,000 galls. **9.** New Red Sandstone.

Name of Member of Committee asking for information, C. E. De Rance, through Mr W S. Aveline.

Name of Individual or Company applied to —

John Vivian, C E, for the Diamond Boring Company, Furness District

1 Rampside, near Barrow-in-Furness **2.** 25 ft **3** 8 in hole at surface and 3 in at bottom, 2,210 ft deep **4** Water cut at 250 ft from surface, and will rise about 12 ft above surface in an inch pipe **5.** 13,500 galls flowing out of hole daily **6.** Always running about the same quantity for the past 4 years **7** A beck runs within 5 ft of hole, but at 5 ft lower level than top of hole **8** Peculiar water was cut in the petroleum-bearing sandstone, but it only flowed from that place for a short time **9** Water was cut in the New Red Sandstone, drift about 100 ft thick, consisting of gravel, sand, boulder-clay and cobbles **10** No, but a little water was found on top of rock **11** Tubed out of hole. **13** Brackish water impregnated with petroleum-oil **14** None.

YORKSHIRE

Messrs Mather and Platt

1 Messrs Bolckow Vaughan, Middlesboro' **3** 18 in diameter, 1132 ft deep **5** 806,400 galls **9** New Red Sandstone. See section of upper portion, previously published in last report

Name of Member of Committee asking for information, C. Fox-Strangways.

Name of Individual or Company applied to.—

Messrs. Steward and Sons *

1. Messrs. Steward & Sons, Comb Works, Walmgate Bar, York. **2.** About 50 ft. **3.** 8 yards to bottom of shaft, 40 yards to bottom of first bore-hole, 120 yards to bottom of second **4** Water stands at about 22 to 23 ft. from surface. **5.** 500 galls. per minute from 3 bore-holes.

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* The present owners of these wells do not appear to know much about them, therefore I have filled in the form from information previously obtained, and from my own personal knowledge of the locality —C F-S

		yards
9.	Clay and stones	8
	Sand	20
	Fine sandstone	18
		46

The other bore-hole went to a depth of 120 yards **10.** Probably. **12** The geology of the solid strata around York is too much obscured by drift to be sure on this point **13** No. **14** No **15** No.

Rev R D Owen.

1. In the centre of St. James's Square, Borobridge **2** I believe about 30 ft. **3.** 256 ft, diameter 4 in bore-hole **4.** Before 17 ft, after 36 hours pumping a reduction of 2 inches in the bore-pipe **5.** Number of gallons would depend on the kind of pump used Supply of water is supposed to be unlimited **6** The pump above is not yet in full work, wells in this neighbourhood vary very little at different seasons of year. **7.** Surface-water cut off to depth of 158 ft from top by iron (30 ft 6 in) and copper (158 ft) pipes **8.** *Vide* analysis already sent to you. **9** *Soft red sand* with boulders in it 28 ft thick, remainder New Red Sandstone, with about 4 layers of red marl 3 to 4 in thick. **10** Yes. **11.** Yes. **12** No. **13.** No. **14** No. **15.** No

Messrs Brett, Sparringate, York

1 My own **2** 18 ft * **3** 80 ft **4** 6 ft from surface. **5** Constant flow 14-inch pipe. **6.** Not more than 2 ft at any time **7** Not at all, not any communication. **8.** Much peculiarity, analysis enclosed **9** Clay, sand, white sand, at 70 ft, at which depth a piece of oak was pulled up in good preservation, 100 ft ironstone and sand, sand continued more or less to 130 ft, gravel, sand, and water, came up pipe out of ironstone at 180 ft. **10** No. **11.** Yes. **12.** No. **13.** No. **14.** Do not know **15** Not to my knowledge

Dr Gill, Bootham Asylum, late of the North Riding Asylum, York.

1. North Riding Asylum, Clifton, York (north side of Asylum) **2.** 40 ft **3.** There is no well, bore-hole begins at surface, depth of bore-hole 232 ft 9 in., diameter 12 in at surface, narrows to 6 in **4** 8 ft from surface before pumping, after pumping 24 hours, at 7000 galls an hour, water lowered 9 ft from water-level. **5.** 70,000 galls have been pumped a day without altering the level of 17 ft from surface **6** I do not know **7** I do not know No surface-water can get into the bore-hole, as it is tubed with an iron pipe nearly to the bottom **8** The water is an ordinary hard water, contains only a small percentage of sulphate of lime, but quite an appreciable quantity of iron, it is very drinkable **9.** 1st, 7 ft of sand, 1 ft of peat moss, 13 ft dense blue clay, 23 ft dense blue clay, containing boulders, many of which are ice-worn, 10 ft red sand, 16 ft soft red sandstone (with layers of slate ?), 23 ft white sandstone, 25 ft red sandstone, with layers of red clay and soft slate, 10 ft white sandstone, 6 in red clay, 20 ft red sandstone, 8 ft white sandstone, 1 ft red clay, 15 ft. white sandstone; 3 ft red sandstone, 2 ft white sandstone, containing large quantities of water, 11 ft white sandstone, 42 ft. red sandstone to well-bottom **10.** Yes **11** Yes **12** Not that I know of **13.** No **14** Not salt springs, but some iron springs much stronger than this water has been found in boring in York **15.** Not that I know of, the bore-hole, I hear, was discontinued on account of the large quantity of iron the water contained

APPENDIX.

Abstract of Analysis of Waters from the New Red Sandstone given in the 6th Report of the Royal Commission of Inquiry into the Pollution of Rivers. (Table, p 108)

The numbers in the Table can be converted into grains per imperial gallon by multiplying them by 7, and then moving the decimal point one place to the left. The same operation transforms the hardness in the Tables into degrees of hardness on Clark's scale.

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* This must probably mean 18 ft. above level of River Ouse. The well is about 30 ft ove sea-level

COMPOSITION OF UNPOLLUTED WATERS FROM DEEP WELLS IN THE NEW RED SANDSTONE

	Depth of Well and Bore hole in feet	Temperature Centigrade	Dissolved Matters in parts per 100 000											Remarks
			Total Solid Impurity	Organic Carbon	Organic Nitrogen	Ammonia	Nitrogen as Nitrates and Nitrites	Total Combined Nitrogen	Previous Sewage or Animal Contamination	Chlorine	Hardness			
											Temporary	Permanent	Total	
BIRKENHEAD, CHESHIRE.														
Well at Spring hill Waterworks	399		16·80	·041	·038	0	·366	·404	3,340	3·40	·2	9·7	9·9	Clear and palatable
Well at Flaybrick hill Waterworks	527		14·20	·047	·015	0	·175	·190	1,430	3·48	·8	4·9	5·7	
BIRMINGHAM														
Well at Messrs R Heaton's Mint	300	10·2	31·32	·052	·016	0	·995	1·011	9,630	3·60	·0	15·8	15·8	Slightly turbid. Palatable
BIRMINGHAM WATERWORKS														
Aston Well	460	10·8	19·42	·034	·006	0	·176	·182	1,440	2·00	9·7	5·4	1 ·1	Clear and palatable.
Perry Well		12·0	23·24	·031	·007	0	·439	·476	4,370	1· 5	7·8	6·6	14·4	
Shortheath Well, Witton		10·2	15·08	·009	·004	0	·447	·451	4,150	1·30	4·6	5·1		
King's Vale Well		12·5	18·06	·037	·012	0	·677	·689	6,450	1·80	3·8	7·4	11·2	Slightly turbid. Palatable
KIDDERMINSTER														
Well in Messrs Brenton's Carpet Mill	160	12·2	18·26	·015	·004	0	·169	·173	1,370	1·60	4·8	6·6	11·4	Clear and palatable
LIVERPOOL WATERWORKS														
Soho Well (closed)	123		59·98	·066	·024	·001	2·195	2·220	21,640	7·51	3·9	16·2	20·1	
Bootle Extension Well	312	10·4	34·40	·091	·027	·001	·418	·446	3,870	3·18	0	13·7	12·6	Very turbid. Palatable
Green Lane Well	370	11·0	26·40	·020	·020	0	·416	·456	3,840	2·68	4·0	9·6	13·6	Slightly turbid. Palatable
Dudlow Lane Well	245		19·64	·604	0	·003	·6 9	·681	6,500	2·61	·5	6·5	7·0	Turbid. Palatable
Winsor Well	453	11·2	32·00	·076	·033	0	·411	·444	3, 90	2·87	2·1	12·8	14·9	
Water Street Well	156		51·42	·018	·013	·001	1·975	1·989	19,449	7·94	1·6	11·6	13·2	Clear and palatable
NOTTINGHAM														
Mr Thackray's Well in town	201		62·84	·050	·020	0	3·508	3·528	34,760	5·60	9·6	10·2	19·8	
Water Supply from Baythorpe Well	120		26·04	·027	·007	·002	·817	·826	7,870	1· 0	14·9	11·3	26·2	Slightly turbid. Palatable
Mr Fisher's Well	200		45·82	·039	·035	·005	2·036	2·075	20,080	3·35	13·8	15·9	29·7	
Baythorpe Well, Nov 1871	120		24·80	·026	·019	0	·770	·789	7,380	1·80	10·4	11·0	23·6	Clear and palatable
ST HELEN'S, LANCASHIRE.														
Waterworks Well	270		21·66	0	0	0	·436	·436	4,040	1·94	5·9	6·8	12·7	
TRANMERE, CHESHIRE.														
Water Supply, May 1868	428	10·4	22·14	0	0	·004	·274	·278	2,450	2·88	2·8	8·5	11·3	Clear and palatable
WALLASEY, CHESHIRE.														
Water Supply	246	11·0	37·80	·030	·008	·002	·278	·288	2,480	3·18	1·2	7·9	9·1	

Wolverhampton														
Goldthorn-hill Well, Waterworks ..	180	10·1	40·40	·041	·014	·0	·714	·728	6,822	2·00	19·1	10·3	29·4	Clear and palatable
Artesian Well, Waterworks			25·46	·032	·011	·0	·037	·048	50	1·90	9·7	11·8	21·5	Slightly turbid Palatable
Tettenhall Well, Waterworks .	.		31·68	·064	·023	·002	163	188	1,330	1·70	17·5	11·3	28·8	Clear and palatable
Worksop														
Deep bore of Prior Well, Brewery Co., Oct. 1873 . .	214	11·0	30·08	·026	·006	·003	0	·009	0	3·60	10·9	17·9	28·8	
Bore-hole at Lady Lee .	.		39·32	·048	·007	·022	0	·025	0	3·50	15·6	20·0	35·6	
Average (of 28 samples) ...		...	30·63	·036	·014	003	117	·734	6,895	2·94	7·4	10·5	17·9	

Composition of Spring-water from the New Red Sandstone

Atherstone, Warwickshire														
Higher spring proposed for Supply			16·10	·068	·028	·002	·054	·084	240	1·70	0	10·1	10·1	Clear and palatable
Birmingham														
James's Spring below Witton Reservoir		9·7	15·54	·052	·019	·011	504	524	4,730	1·75	·0	8·3	8·3	
Coventry														
Allesley Road, spring entering tank		10·8	32·66	·067	·018	0	338	356	3,060	1·70	15·7	9·5	25·1	
Flowing Spring from bore-hole	200	10·8	26·88	·018	·004	0	306	310	2,740	1·60	11·1	8·0	19·1	
Hugglescote, Leicestershire														
Mr Griffin's Spring in Donington	. .		33·86	104	·027	0	234	261	2,020	1·40	19·8	15·9	35·7	Slightly turbid Palatable
Nottingham.														
Spring in Forest		.	21·96	·032	0	0	844	844	8,120	1·60	0·9	11·0	11·9	Clear and palatable
Sudbury, Derbyshire														
Spring near village ...			20·30	056	·014	0	354	368	3,220	1·30	9·3	7·0	16·3	Slightly turbid Palatable
Leek, Staffordshire.														
Spring, Staffordshire Potteries			13·84	·031	·015	0	146	161	1,140	1·30	4·7	4·2	8·9	Clear and palatable.
Warrington														
Spa Spring near Winwick .		.	24·34	·027	·002	0	310	312	2,780	1·64	7·9	10·2	18·1	
Knutsford, Staffordshire.														
Spring at Rosthorne			33·76	·070	·013	·061	1·256	1·275	12,250	3·25	4·9	15·7	20·6	
Runcorn, Cheshire														
Fountain .			60·80	118	·011	0	382	393	3,510	7·00	8·1	17·2	25·3	
Hurworth, Durham.														
Spring at Cross Bank Hill . .			74·26	·080	·006	0	·0	·006	0	3·37	4·0	25·0	29·0	
Average (of 15 samples) .. .	.		28·69	·065	·017	·001	330	349	3,047	2·19	8·1	10·7	18·8	

Fourth Report of the Committee, consisting of Professor HARKNESS, Prof. PRESTWICH, Prof. HUGHES, Rev. H. W. CROSSKEY, Prof. W. BOYD DAWKINS, Dr. DEANE, Messrs. C. J. WOODWARD, L. C. MIALL, G. H. MORTON, *and* J. E. LEE, *appointed for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the more important of the Erratic Blocks of England and Wales, reporting other matters of interest connected with the same, and taking measures for their preservation. Drawn up by the* Rev. H. W. CROSSKEY, *Secretary.*

THE Committee has pursued the same course as during former years. The time for generalization has not yet arrived. There are many erratic blocks scattered over the country as yet unrecorded, and their character and distribution will largely affect any conclusions that may ultimately be reached. The Committee has for its present duty the collection of facts; when its labours have resulted in a complete account of the isolated boulders and groups of boulders of England, Wales, and Ireland, material now unavailable will exist for theoretical discussion, and many important incidents in the history of the glacial epoch will be more accurately determinable.

The importance of the work undertaken by the Committee continues to be emphasized by the destruction which is constantly going on. War is waged upon the boulders (which in many cases are our only source of information respecting the epoch to which they belong) by agriculturists, and builders, and road-makers with unceasing energy. They are built into walls, buried in the earth, used as foundation-stones, and often blasted to pieces; their preservation is difficult to secure, on account of their interference with the culture of the land. In a few years it is not too much to say that the evidence of glacial phenomena will in many districts be almost effaced.

The Committee directs attention to (1) the distribution of erratic boulders from different centres of ice action; (2) the agencies by which they have been transported; (3) the different periods in the glacial epoch to which they belong; (4) the heights above the sea at which they are found, indicating large changes in physical geology.

The schedule of inquiry, indicating the various points of the information required, printed in a former Report, has been issued, and copies may always be had on application to the Secretary of the Committee.

DEVONSHIRE.

A very remarkable group of boulders has been reported upon by Mr. George Doe, of Great Torrington.

It is found in the estate of Rivalton, in the parish of Langtree, Devon, about four miles from Great Torrington.

The dimensions of the largest boulder of the group are 13 ft. × 6 ft. × 3 ft. It is subangular in form; but there are no groovings or striations. It rests on clay, close to a small brook, and is about 500 feet above the sea-level. The only legend connected with it is the old story of its having been thrown by the Devil.

At the distance of about 25 ft. N.E. is another boulder 3 ft. × 3½ ft. × 2¼ ft. At a distance of 35 yards are six small boulders, cropping out from the ground.

At a distance of nearly half a mile are three more, similar to the last mentioned

Near them is a deposit of flints in clay and a gravel pit

All these blocks except the first are south of the large boulder

These boulders consist of felsite, resembling that in many of the "Elvans" A felsitic Elvan, at Tresavean, Gwennap, Cornwall, cannot be discriminated from them Possibly, however, a nearer locality may be found

OXFORDSHIRE

Professor Prestwich describes a boulder found last summer near Oxford in a bed of subangular flint gravel (high level river gravel), at Wolvercote brick pit on the high road from Oxford to Woodstock, at an altitude of about 40 feet above the level of the river Isis

It consisted of a mass of hard saccharoid sandstone of concretionary origin, some portion of it broken away, and the broken edges quite angular it weighed about three tons It bore no trace of ice scratches There were no fossils to identify the sandstone but from general characteristics, Professor Prestwich thinks that it is of Tertiary origin Several smaller boulders, of from ½ to 2 or 3 ft cube, more or less worn, were dispersed irregularly through the gravel, which is scarcely at all stratified, and contains no fossils

MIDLAND COUNTIES

Dr Deane and your Secretary have examined numerous boulders in the neighbourhood of Harborne, to W and S W of Birmingham, between the Hagley and Bristol roads

One hundred and sixty rounded and subangular masses of stone have been examined in this district Fifty five of these are clearly traceable to local rocks—Carboniferous, Permian or Triassic the remainder are of distant origin

Very few of these travelled boulders are *in situ* They have been rolled or dragged off the land into ditches and by roadsides Some, when the size has been convenient, have been used by the "nailers of the district for hammering (or rather anvil) purposes

Ninety are of the varieties of felstone so abundant in the Bromsgrove district About half of these are of small size Five are of considerable magnitude—5 ft 6 in × 5 ft × from 2 to 3 ft , the rest are from 2 to 4 ft in length and breadth, with variable thickness One of these felstone boulders (near Hole Farm, Moor Street, about two miles east of Hales Owen) is worthy of special notice Its dimensions are 3 ft 0 in × 2 ft 6 in × 2 ft , and it contains in one specimen the three characteristics named in a previous report as occurring separately in the boulders of Bromsgrove A compact, almost hornstone-like matrix contains distinct included fragments and porphyritic felspar crystals This specimen, therefore, confirms the view that these felstone boulders, which are so numerous to the west and south of Birmingham, as far as and beyond Bromsgrove, are portions of highly indurated ash-beds

At Flavell's Farm, California, is one boulder of grey granite 2 ft by 1 ft 8 in. by 1 ft. Vein-quartz and quartzite constitute nine small and three large boulders, and one of these, found near Harborne station, contains included brecciated fragments of rock The size of these quartzite boulders, the largest of which measures 3 ft × 2 ft 6 in × 2 ft negatives the idea that they have come from the Bunter pebble-beds

The general character of the boulders of this district is similar to that of the Bromsgrove district but in the presence of granite quartz and metamorphic rock resembles the district north and west of Wolverhampton

North and west and south west of Wolverhampton however granite is very much more abundant than in the district west and south west of Birmingham The large boulders north and west and south west of Wolverhampton are it is probable chiefly Criffell or (more sparingly) Wigtonshire granite*, but there is Eskdale granite in the neighbourhood especially about Bridgnorth

The Welsh felspathic drift covers abundantly the west and south west of the Midland tableland while felspathic rocks from the Lake district accompany the Eskdale granite and are often mixed with the Criffell granite

The boulders occur in two distinct positions (1) in the older glacial beds (2) in the upper clay

LANCASHIRE

Large striated boulders have recently been exposed in the extensive excavations which have been made in the boulder clay at Bootle a northern suburb of Liverpool The site excavated is intended for new docks and extends along the river Mersey, being reclaimed from shore within the tidal range

Mr G H Morton describes for your Committee the position of these boulders, and gives the following section of the drift deposits which have been exposed continuously over many acres The thickness of the various beds varies considerably according to position and the middle sands and gravels often thin out and leave the upper boulder clay reposing on the lower

Section

1	Sand and silt, old Bootle shore	17 feet
2	Upper Boulder-clay	15 „
3	Sands and gravels	6 „
4	Lower Boulder clay	6 „
	Upper Bunter Sandstone	

The whole of the subdivisions 1 to 4, repose in succession on the Bunter Sandstone at that part of the section nearest the old coast line

The Lower Boulder clay contains a much greater quantity of small stones than the Upper Clay No large boulders were observed but as the Lower Clay is not exhibited to any considerable depth it may possibly contain some

The Middle Sands and Gravels consist of sands which frequently, by the great increase of rounded pebbles become gravels, resembling those at Preston Junction Wigan, Gresford, and Colwyn

The Upper Boulder-clay contains comparatively few small smooth stones, but many large boulders two or three feet in diameter Many of these are striated, and are composed of greenstone, but some are Eskdale granite These large boulders possibly occur at an average distance of twenty yards from each other A large mass of compact gypsum, about 4 feet in diameter, was noticed

The sections described are still exposed at the present time, August 1876

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* See paper by Mr Mackintosh Quart Journ Geol Soc vol xxix p 358

CUMBERLAND.

Prof. Harkness reports that a boulder of Silurian conglomerate (the Queensbury grit of the Geological Survey) occurs at the village of Bothel, in the parish of Sorpenhow, North Cumberland In length it is about 20 feet, in height 9 feet, in breadth 8 feet. It is beautifully striated on the western side. It is situated between the 400 and 500 feet contour-line, and has been transported from the north-west portion of Dumfriesshire, having travelled about forty miles from N N W. to S S E.

This boulder goes by the name of "Samson"

Prof. Harkness further reports that some fragments of Shapfell (Wastdale crag) granite occur in a field in the farm of Hindrig, near Dufton, Westmoreland, at about 800 feet above the sea-level. These have for the most part been blasted, and many fragments occur in the wall adjoining. Some of the blocks are untouched, but these are so imbedded in the soil that their size cannot be determined

There are also several small blocks of this granite in gravels, which Prof Harkness regards as Eskars, in a gravel-hole on the farm of Luhan, in the parish of Edenhall, about three miles east of this. Near the village of Newton Reigny, about two and a half miles west from Penrith, large boulders occur. They are so imbedded in the soil that their size cannot be determined. They consist of the Lower Silurian trap of the Lake country Boulders of the same kind and of a large size are also seen on the east side of Newton Moss, which is a short distance S W. of the village The height of these Newton boulders is about 600 feet above the sea

NORTH WALES.

Mr. D. Mackintosh contributes the following account of the boulders in North Wales. An account of previous observations will be found in the Quart. Journ. of Geol. Soc., Dec. 1874.

Between a mile and a mile and a half west of Llan-y-cil, on the north-west side of Bala Lake, the glacial striæ in several places average between 45° and 50° north of geographical west, and the boulders are of precisely the same kind as would have come from about the north-west or from the neighbourhood of Llyn Arenig. Both the direction of the striæ and course of the boulders would cross Bala Lake at nearly right angles to its length; so that if the basin of the lake had ever been scooped out by land-ice, this ice must have come from the south-west before the period of the great boulder transportation from the Arenig mountain.

At the south-west end, and along the south-east side of Bala Lake, many of the boulders are not the same as those from the Arenig mountain, which are chiefly found on the north-west side, and they decrease in number north-eastwards, suggesting the idea that they came from the south-west.

Through the gap immediately south of Moel Ferna, numbers of boulders appear to have found their way into Glyn Ceiriog, and east as far at least as Chirk. Numerous large boulders have gone nearly due east along the valley of the Dee, as far at least as Cefn and Ruabon The east and north-east boundary of the Arenig dispersion may be roughly defined as extending from Chirk by Cefn, Ruabon, Wrexham, Caergwrle, Mold, and the east side of Halkin mountain to Holywell, and thence in a westerly direction to the vale of Clwyd. This line nearly coincides with the boundary of the great northern granitic drift. Both drifts (the Welsh and northern) have, to a slight extent, crossed the average boundary, and a few small Arenig boulders have found their way across the estuary of the Dee into the peninsula of Wirral, where they have become mixed with the very abundant northern drift from the Lake district and the south of Scotland.

The western boundary of the Arenig felstone drift would appear to run from the Arenig range in a N.N.E. direction as far at least as the celebrated Cefn Cave, near St. Asaph, where, to a slight extent, it has become mixed with the northern drift, and likewise with erratics probably from the neighbourhood of Conway. Few or no boulders from the southern part of the Snowdon range would appear to have found their way over the high tablelands situated to the east of Llanrwst and Bettws-y-coed, the Snowdon dispersion having radiated in all directions *to short distances only*, excepting towards the south. This Arenig dispersion is one of the most remarkable in South Britain. The felstone boulders from the Arenig range have radiated to great distances over an area extending from N.N.E. to E., and to short distances from E. to S.E.—that is, over the fourth of a circle. The boulders have found their way across valleys and over watersheds and high mountains. In most places they have wholly ignored the configuration of the ground, excepting where gaps in mountain-ranges have facilitated their transportation. A detailed examination of the surface-configuration, viewed in connexion with the positions occupied by the boulders, would seem to favour the idea that they could only have been carried by floating ice; but it ought to be observed that there is an apparent distinction between the large angular and subangular boulders which are seen chiefly on the surface, and those smaller and well-glaciated boulders which are found imbedded in the Lower Boulder-clay at comparatively low levels.

Among the Arenig felstone boulders, which are so remarkable for size, for the unexpected routes they have taken, or for the distances they have travelled, as to render them worthy of being preserved, the following may be mentioned:—(1) The Cefn boulder, a short distance west of Cefn station, near Ruabon, which measures 15 × 14 feet, and at least 10 feet in depth; (2) the *Maendigwychyn*, or great immovable stone in the village of Eryrys, near Llanarmon (about 5 miles east of Ruthin), which measures 15 × 15 × 12 feet, and is situated about 1130 feet above the sea; (3) a boulder in a field near Bryn-Cloddian, north-east of Caerwys railway-station, and a few miles south-west of Holywell.

The direction of glacial striæ on rock surfaces in the eastern part of North Wales, as well as in the neighbourhood of the Arenig mountain, Corwen, &c., in general agrees with the course the boulders have taken. On the summit of Halkin mountain, in a quarry a short distance west of Holywell, there are well-defined striæ, indicating the passage of ice from the south-west; and in the neighbourhood of Llangollen, especially near Trevor (as lately ascertained by Mr. Morton, F.G.S.), there are several instances of striæ pointing from west to east.

Fourth Report of the Committee, consisting of Sir John Lubbock, *Bart.*, Prof. Prestwich, Prof. Busk, Prof. T. M'K. Hughes, Prof W. Boyd Dawkins, Prof. Miall, Rev. H. W. Crosskey, *and* Mr. R. H. Tiddeman, *appointed for the purpose of assisting in the Exploration of the Settle Caves* (*Victoria Cave*) *Drawn up by* R. H. Tiddeman, *Reporter.*

The Committee have to report that work has been carried on at the Victoria Cave throughout the year, with the exception of the interval from the 24th December, 1875, to January 3rd, 1876, and that the Settle Local Committee have expended during the year ending August 13th, 1876, the sum of £90 13*s.* 3*d*, besides the grant of £100 entrusted to them by the British Association

A considerable amount of work has been done in the course of the year in excavating the central chamber A and that which lies to the right of it, called D. These, though formerly separate chambers, are now seen to form one large one. They consisted at first of mere spaces between the roof and the cave deposits, which had not been filled up entirely by the latter, branching off from one another and merely communicating at the bifurcation. From the lowering of the deposits by excavation, they now form only one large and long entrance-hall to the remainder of the cavern, and the old line of demarcation can now only be distinguished on the present ceiling by the following circumstance. Chamber A cuts higher into the roof than chamber D, and is marked off from it by a line of joint, along which a thick bed of limestone has fallen down on to the floor in chamber A, but still forms the roof of chamber D. This huge block, which extended a distance of about 60 feet, from about Parallel 15 to 44, at the extreme end of chamber A, has given us great trouble in the course of the year, partly from its size, and also because, being fissured by cracks here and there and lying on a clayey layer, it was subject to successive slips. Considerable downfalls threatened from time to time, and these had to be anticipated by quarrying it away. The large body of laminated clay which has been described in former reports ended off for the most part against this block towards the north, and must have been deposited against it. This is the mass of laminated clay which overlay the bone-beds containing the older mammals *Elephas antiquus*, *Rhinoceros leptorhinus*, *Hippopotamus*, *Hyæna*, and others, with Man.

There can be no doubt now, to whatever agents the formation of that interesting deposit be due, that there are somewhat similar beds also underlying that Pleistocene bone-bed in places. From about 2 feet Parallel 10 as far as present workings inwards at Parallel 30 an exceedingly dark, tough, waxy clay lies below that layer. It varies much in thickness, from 7 or 8 feet on the right or east side of the cavern to lesser dimensions towards the west, and eventually loses itself amongst large fallen blocks of limestone on the left.

A thin layer of stalagmite, varying from 8 inches to a mere film, occurs at the base of the above clay. It is often very fibrous, and in some places it has a distinctly greenish hue. At the suggestion of the Committee, Dr. Marshall Watts kindly analysed it; and his report is as follows:—

"The mineral is as nearly as possible pure Calcium Carbonate. It contains no Phosphoric Acid. Its specific gravity is 2·879, that of Calcspar varies from 2·70 to 2·75, and of Arragonite from 2·92 to 3·28, so that for a non-crystalline deposit of stalagmite the agreement is sufficiently close.

(Signed) W. M. Watts."

To return to our section Here and there this stalagmite rises into small bosses, showing that its existence was mainly owing to the dripping of water from the roof. It forms a kind of dotted line of demarcation between the dark clay above and the layer next to be described beneath.

The bed beneath this stalagmite is somewhat like the dark clay above it in arrangement, but is not of so fine a texture. Its colour is much lighter, a yellowish brown. It is somewhat sandy, presents on digging a rougher section than the waxy lustre of the dark clay above, and is more clearly laminated, though the laminations in it are wider apart. This clay appears to follow the upper surfaces of the fallen blocks on which it rests, and is rudely parallel with them. We find that as these blocks rise in successive steps towards the south-west, so this clay rises on them, and covers them continuously at higher and higher levels.

There is one point about this lower light-brown laminated clay which is of much interest; channels appear to have been formed in it. Hollow troughs occur, which may perhaps be due to its subsidence through chinks in the rocks beneath, or they may have been formed by little streams of water cutting out channels subsequently to the formation of the main mass of it. However they were formed, the thin overlying stalagmite appears to have made a thin coating over their walls simultaneously with the like formation on the flatter surfaces between them. The overlying dark waxy clay, on minute examination, is seen to dip into these cavities sometimes at a considerable angle. It is only possible to see this lamination when the clay is cut with a clean knife; the spade obliterates the bedding This arrangement of the layers at the sides of the trough would seem to point rather to our first hypothesis of their formation as being the more probable.

It has been suggested in former reports that the laminated clay which lies above the Hyæna-bed may possibly be the result of a deposit from glacier water at the time of the ice-sheet, it being now distinctly proved that the animals whose bones occur some distance beneath it existed in that district at a time prior to that cold period. The chief evidences for this last consist of—(1) the superposition of the boulder-deposits at the entrance of the cave upon the edges of the bone-bed, and (2) the total removal of the remains of these animals from the *open* ground in those particular areas where direct evidence of the former extension of an ice-sheet exists.

We must not forget, however, that further south and east the same animals are found in the river-gravels under such circumstances as imply that a cold period occurred also *previous* to their ranging through the country, the gravels being of later age than certain glacial beds in the south and east of England. These facts imply that the animals whose bones are found in the lowest known bone-beds in the Victoria Cave lived in this country in the course of a well-marked interval between two periods of extreme cold, and that the earlier left traces of its effects further south than the later. It is therefore within the limits of possibility that this lower waxy laminated clay is a representative in time of some of the earlier glacial beds of the south-east of England The subject, however, is an extremely wide one, and our present knowledge of the age and succession of the drifts must receive many additions before such an hypothesis can be either proved or disproved.

Bronze Objects.- The Romano-Celtic layer is probably now completely eliminated from Chamber A. That portion of the present large entrance-hall which we used to call Chamber D was apparently never occupied by the folk who used the bronze articles. Chamber B, that to the left of

Chamber A, may still, perhaps, contain some relics of that period, but we have not worked in that chamber for some years, our finds of articles of that age are consequently rare and exceptional. On the 12th of February, 1876, whilst blasting and removing a portion of the huge fallen mass of limestone already referred to, a bronze harp-shaped fibula was found, in good preservation, with traces of its iron pin. It was in Parallel 16, 5 feet left of the datum-line, and at a depth of 9 feet, below a chink in the limestone block; and, as Mr. Jackson suggests, there is every probability of its having fallen down the crack from above. Whether dropped there by one of the cave refugees, or fallen down a crack which had been enlarged by the settlement of the blocks consequent on the explorations, is immaterial. It was certainly far below its natural level, and the block of limestone beneath which it was found extended up to the Romano-Celtic floor.

Another object in bronze was found during the year upon the old upper tip. It is in the form of an ovate leaf, with a broad midrib and rude veining; the apex of the leaf is broken off. Where the leaf-stalk would be is a quadrate expansion pierced with a rivet-hole. It is 1·5 inch long and 1·1 inch broad, and curved in the direction of its length.

Animal Remains.—Professor Busk has again kindly examined the bones, and given their determination in a register. He remarks, —

"As usual, the collection is chiefly interesting on account of the large proportion of Ursine remains, some of which, as you will perceive, I am inclined to assign to *Ursus spelæus*, but most belong to the *ferox* type, whilst some few could not be well distinguished from *Ursus arctos*. Some of the bones are remarkably perfect, and have the same polish as that already recorded. The only addition to the former fauna, if I remember rightly, is *Mustela martes*. There is also a remarkably small fox, but not *Canis lagopus*.

(Signed) G. BUSK."

Amongst the remains returned by Prof. Busk is a lower jaw of Weasel. This was found in the Lower Cave-earth, beneath the boulders; so that that is another addition, besides the Marten, to our list of animals from the early Pleistocene layer.

In speaking of the animals found, the place of honour necessarily falls to the *Hyæna*—not by reason of the number of his remains discovered, but because to him we are indebted for by far the larger number of bones of other animals introduced. It is, indeed, singular to note that, notwithstanding the abundant evidence of his presence, from the characteristically gnawed and cracked bones of other animals, we have hardly any remains of him this year except teeth. There can, indeed, be scarcely a doubt that a dead hyæna was as acceptable to his survivors as the carcass of any other beast.

Of *Bear* we have found a fine series of tusks. We have already given Prof. Busk's remarks upon them. A very large humerus, which he attributes to the Grisly Bear, was found in Parallel 21, at a depth of 12 feet. From the way in which its proximal extremity has been gnawed off, and some of its more prominent ridges removed, there can be no doubt that it was coexistent with Hyæna. Some remains of very young Bears have been found—so young, indeed, as to make it doubtful whether they ever had an independent existence.

Of *Rhinoceros* we have a femur, found in Parallel 30, at a depth of 7 ft. 6 in. It has been gnawed, as such bones always are, by the Hyæna, and to the usual extent. Several exceedingly fine teeth of Rhinoceros have been found since the bones were submitted to Prof. Busk, and their determination must be for the present postponed. A lower premolar 4 of Rhinoceros, which was the first of that animal found in the cave, together with the human fibula, and hitherto supposed to be *R. tichorinus*, is now considered by Prof. Busk to be *R. leptorhinus*.

Of *Deer* found this year we have several. One is a base of an antler with brow-tine (*Cervus tarandus*), but the species is marked as doubtful; another tine is doubtfully referred to *C. elaphus*; another is a fragment of a very large antler, and no species is assigned to it; also there is a patella of a very large deer, which was near the surface.

Of *Goat* several remains have been found; and it would almost seem possible, from the depth to which some of them occur, that this animal may have existed in Britain at an earlier age than has usually been assigned to it; but we cannot put forward this idea confidently without further confirmation. One humerus of an exceedingly small Goat has cuts upon it which are evidently human workmanship, but there are circumstances which render it desirable to reserve any further remarks upon it to a future occasion.

In our last year's report we called attention to the existence in the Victoria Cave of a "fauna which we may confidently assign to a cold climate, separated in some parts, by an accumulation of deposits 12 feet or more in thickness, from an earlier one, which is equally characteristic of high temperatures, whereas in another part of the cave not far off, where the material to separate them is wanting, we have animals from icy and tropical countries intermingled in a confusion which would be puzzling did we not get the clue hard by." We remarked that it was evident that the separation was natural and regular, the mixture abnormal and accidental. "As distinguished from the lower bed, the chief characteristics of the upper were the presence of the Reindeer, and the absence of Elephant, Rhinoceros, Hippopotamus, and Hyæna." These remarks were made solely on the evidence which passed through your present reporter's hands since he undertook to conduct the exploration of the cavern. Prof. W. Boyd Dawkins has kindly written to remind us that Reindeer was found in the lower cave-earth, below the laminated clay, when he had charge of the explorations, and he has no doubt that it was dragged in by Hyænas. The Hyæna-bed at that spot, viz. the mouth of the cavern, was at a depth of 16 feet below the laminated clay, and your reporter had an impression that the Reindeer-remains occurred at some height above the Hyæna-bed. Be that as it may, Prof. Dawkins's opinion is entitled to great weight, and is, indeed, the view generally held. At the same time, considering that Hyæna and Reindeer are not uncommonly found together in caves, when, as in this case, we see them mixed together at one or both ends of a section but separated through an interval of 70 feet in length by a thickness of deposits, we may regard the fact as at least an interesting one, and, when found, noteworthy.

The excavations still throw light upon how the Cave was formed. As far as we have yet worked at the present level, the right wall of the cave is seen to have been hollowed out by streams. Several grooves occur, indicating water-levels, but, except quite at the entrance, we have not got down to the ancient floor. We are already working in deposits which are probably of greater age than the older Thames gravels. The river is now running 900 feet below us. What earlier records we may disentomb we cannot tell; we must work on and wait.

Report on Observations of Luminous Meteors during the year 1875–76, *by a Committee, consisting of* JAMES GLAISHER, *F.R.S.*, R. P. GREG, *F.G.S.*, *F.R.A.S.*, C. BROOKE, *F.R.S.*, Prof. G. FORBES, *F.R.S.E.*, WALTER FLIGHT, *D.Sc.*, *F.G.S.*, *and* Prof. A. S. HERSCHEL, *M.A.*, *F.R.A.S.*

[PLATE IV.]

THE principal subjects of discussion in the present Report are, as they have been in former years, the descriptions of meteors and meteor-showers of which the Committee has received information during the interval of a year which has elapsed since the presentation of the last Report.

Of such materials a large supply has as usual been contributed to, or has been sought for by, the Committee. Most of the appearances described are fireballs of an occasional character, some of which have given rise to a good deal of remark and scientific discussion in the public journals of the day, both from the exceptional character of brightness and from the quick repetitions of their occurrence.

Large fireballs were seen on the 3rd, 7th, and 14th of September last, which were observed over such a considerable extent of country as to allow of their real heights and paths to be calculated with a somewhat unusual degree of accuracy. The paths of these meteors were calculated by Captain G. L. Tupman, of the Royal Observatory, Greenwich; and very satisfactory conclusions were arrived at as to the probable meteor-showers or systems to which these large fireballs, two of which were detonating, appear pretty certainly to have belonged.

Other instances have occurred where bright fireballs have been seen at several points in England sufficiently far apart, and have been observed with sufficient accuracy to lead to definite although not generally more than very rough determinations of their actual heights, velocities, and directions. One of the largest of these bolides was seen in bright sunshine on the 22nd of December, 1875; another of great brilliancy was noticed on the evening of July 25th, 1876; of these meteors, as only a few well-recorded descriptions were obtained, the probable real paths are only generally indicated, or have only hitherto been provisionally computed. Meteors of this conspicuous character appeared also on the 16th of August, 1875, and on the 15th of April, 11th, 13th, 15th, and 21st of August in the present year. Some heights of shooting-stars observed in the August shower in 1874, and described in the Catalogue of last year's Report, are deduced from the observations, and are here presented as completely as the accuracy of the observations would permit.

The occurrences of meteor-showers during the past year have been very slight and ill-defined, with the exception of the August-shower displays of 1875 and of the present year. The present year's recurrence of the August shower was, however, less plentiful than has been visible for several years past, and has amounted to a real minimum of intensity of its annual apparitions.

A new general catalogue of meteor radiant-points, with an accompanying key-map, compiled during the past year by Mr. Greg, appears in the Report, and a valuable contribution of reviews of the past year's records and examinations of aerolites (of which the many remarkable occurrences continue to increase in scientific importance year by year), by Dr. Flight, concludes its pages. One of the most interesting of such events, it will be recollected, took place this year in England, when a mass of iron weighing 7¾ lbs. fell at Rowton, near the Wrekin; and this, it may be observed, is only the seventh instance where a mass of metallic iron of meteoric origin, or an aerosiderite, has actually been seen to fall. This event took place in Shropshire, at 20 minutes to 4 o'clock P.M., on April 20, 1876.

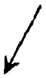
OBSERVATION
IN 1875–76, AND IN

Date.	Hour G. M. T. (or local time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path.
1871 Aug. 11	h m s 12 33 a m	Near Troubridge, Salop	Large meteor			[Perhaps the same as that seen at Cardiff and Bristol at 12h 22m to 23m A M See these Reports for 1872, p 81]
1873 May 14	3 5 a m		About as large as the planet Venus when most brilliant	White	About 3 or 4 seconds	First appeared a little eastward of the moon (then in the S S W), and passing a little below it disappeared to the westward of that luminary at about 15° above the horizon.
1874. Aug. 10	10 15 30 p m.	Lynton, N Devon	Very bright meteor		. . . . . .	Position of the streak $\alpha =$ $\delta =$ From 337½° +5° to 331 +3
10	10 16 p m	Radcliffe Observatory, Oxford	As bright as Venus .	.	. . . . .	From γ to β Andromedæ.
Sept. 6	8 40 p m	Bristol..... ..	= Jupiter .		Rapid ..	$\alpha =$ $\delta =$ From 275° +20° to 255 −12 Passed between β and γ Ophiuchi
13	8 53 30 p m.	Crediton, Devon	= Jupiter . . .	.... .	....	From 15° above the horizon to ι Ursæ Majoris.
Nov. 10	11 0 30 p m.	Bristol .	Brighter than Venus.	.. ..	Very slow .	$\alpha =$ $\delta =$ From 43° +30° to 7 −4
11	9 44 p m	Ibid.	= Venus	..... .	Slow	$\alpha =$ $\delta =$ From 31° − 6° to 24 −13
1875. Feb. 4	9 30 p m	Melrose, Scotland.	Brilliant meteor	.	. . .	Travelling north ..
May 17	8 40 p m	Greenhithe, Kent	About = Venus	Red	About 6 or 7 seconds.	....

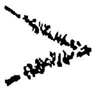
OF LARGE METEORS
SOME EARLIER YEARS.

Length of Path	Direction or Radiant-point.	Appearance, Remarks, &c	Observer or Reference.
... ...	... ...	A very brilliant meteor; lighted up the country Seen after two hours observations of the August meteors on the Wrekin Hill.	G. T Ryves Communicated by G J Symons
. . . .	Descended at an angle of about 40°, from S E. to N W	Died gradually out, and left no visible tail or sparks—perhaps from the brightness of the moon, which was shining with great splendour.	F. V Jacques. Communicated by W F Denning
...	[The recorded courses of this meteor and of the next are not reconcilable with each other.]	Illuminated all objects with a flash like that of lightning On looking upwards, I saw the streak as stated, which remained visible eight seconds.	S J Johnson. Communicated by W. F. Denning.
... ...	... ...	The meteor seemed to burst at β Andromedæ [Identical with the last meteor W F. Denning]	J. Lucas 'Radcliffe Observations,' vol for 1872
37°, long path	Directed from γ Lyræ .	Left a streak almost vertical in S.W. for a second.	W. F Denning.
... ...	... ...	Very bright; left no streak	S J Johnson. Communicated by W F. Denning.
47°	Radiant $F_{1,2}$	Left a long train for 3 seconds	W. F Denning.
9°..	Radiant the Hyades, or α Aurigæ.	Only the end of the flight observed; no visible streak.	Id.
... .	... ...	Falling stars on February 4th at 6^h A.M.	Communicated by G J. Symons
Its visible course extended half across the sky.	From west to east	Nucleus with a continuous tail, and pieces dropping from it at intervals. A faint vapour appeared to precede it, falling back upon it as it sailed along A large and fine meteor.	Extract from a Newspaper; communicated by W. F Denning

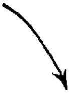
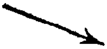
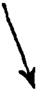
Date	Hour G M T (or local time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1875	h m					
June 2	About 10 30 p m	Wolverhampton	Large		About 7 or 8 seconds	Its course was nearly south east
7	2 15 a m	Melrose, Scotland	Brilliant meteor			
25	11 20 p m	Cambridge	Fine meteor			In the north
July 7	10 54 p m	Bristol	= Jupiter			Passed just under Cassiopeia
8	12 2 a m	Ibid	= Venus			Shot towards the sword hand of Perseus
Aug 1	9 25 p m	Ibid	= Jupiter		Rapid	α= δ= From 126° +53° to 125 +46
8	10 10 p m	Ibid	About = Venus			Shot across or near π Pegasi
16	10 20 p m	The Garden Cliff near St Agnes Cornwall	Large meteor	White, like burning magnesium	Several seconds	From a point in the S E to a little N of E but a few degrees above the neighbouring hills of Penhall's Mine
Sept 2	9 22 p m	Regent's Park, London	Large and brilliant	Rather ruddy		Came from about Corona its course ending about 10 below α β Ursæ Majoris
3	9 52 p m	Radcliffe Observatory Oxford [Royal Observatory Greenwich, &c]	About 3 × ♃ [Disk 15 of dazzling brightness]	Blue changing to green	5 seconds [1 5 or 2 seconds rapid]	First appeared just west of Saturn [Passed between α and β, disappearing close to κ Aquilæ]
4	About 8 45 p m.	West Dereham	Splendid meteor			In the north-west
6	10 0 p m	Bristol	Large fireball			In the eastern sky
7	11 31 p m	Radcliffe Observatory, Oxford, Ipswich, Kent, Surrey, Essex, &c	Brighter than Jupiter or Venus Disk about ¼ apparent diameter of the moon.	Blue with red sparks Blue colour of nucleus very bright	Duration 2 or 3 seconds (Oxford, 6 or 7 secs)	Seven or eight well observed apparent positions of its course.

Length of Path.	Direction or Radiant point	Appearance, Remarks, &c.	Observer or Reference
		Very vivid; made a startling glare in the sky. Nucleus with a long train and a bright flame-like head flickering like a torch carried against the wind	Arthur Hinde. Communicated by G. J. Symons
			Communicated by G. J. Symons
		Very brilliant. Seen also at Calathorpe 11h 20m P.M.	Id.
	Directed from the Pointers in Ursa Major		W. F. Denning
	From the direction of β Pegasi	Left a train for 3 seconds. Immediately afterwards another meteor = Jupiter shot down at right angles to the path of the former one, leaving a streak for 1 second	Id.
7°	From direction of α Ursæ Minoris	Left a very bright train for two seconds	Id.
	From χ Persei, reversed	Visible behind clouds; left a long train	Id.
		Light brighter than that of the moon. Nucleus like a chain of bright beads. Seen also in Wales and in Brittany, France. (See Appendix I.)	F.R.S. The 'Times,' Aug. 19th, 1875
	Sloping downwards towards the northern horizon	A fine meteor seen through clouds which obscured the stars; the apparent path approximate. Nucleus with a broad tapering train visible several seconds after it on its course	T. Crumplen.
11° or 12° [18°]	Descending slightly eastward. [Fell vertically. Radiant point of the projected tracks at 311°, +52°.]	Threw off a spark at disappearance about the apparent size of Saturn. [Ended with a flash of excessive brightness.]	J. Lucas. (See Nature, Sept. 9, 1875; 'Astron. Register,' April 1876, and Appendix I. of this Report.)
			Communicated by G. J. Symons
	Descending slightly inclined from the vertical towards the left 	Nucleus globular; illuminated the sky like a flash of lightning. Seen by many persons at Bristol; the flash seen also by Mr. Denning	Communicated by W. F. Denning
Long course	Radiant point of the projected tracks 347°, +15°	Fireball with train of scattered sparks 10° long. Divided in mid course into two, with flash of blue light, accompanying each other very closely to extinction. Detonated. Left no streak	The 'Times,' Sept. 9. Astron. Register, Oct. 1875, &c. (See Append. I. of this Report.)

Date.	Hour G. M. T. (or local time)	Place of Observation	Apparent Size	Colour.	Duration.	Position or Apparent Path
1875. Sep 11	h m s 11 0 p m	Edinburgh, Burntisland, &c Scotland	Large meteor Extremely bright	..	2 seconds ..	Zigzag course across the Hædulæ in Auriga.
14	8 20 p m	Lynn, Norfolk...	3 or 4 × Venus ...	Pale blue .	....	Close above the E. by N. horizon, which it did not reach before disappearing
14	8 27 30 p m	Royal Observatory, Greenwich, and in all parts of England.	Large disk, nearly apparent size of the full moon.	White or bluish-white, tail of some coloured sparks.	Mean observed duration 8 seconds.	Twelve or fifteen well-observed positions of apparent course.
25	8 25 p m	Bath	About half apparent diameter of the moon.	Various colours.		Descended from not far above the northern horizon, as if with full brightness, to the earth.
25	8 30 p m	Near Bristol .	Nearly half apparent diameter of the moon	White, like Venus	.	Almost due north, from altitude about 40° to about 30°.
Oct. 4	11 32 p m	Bristol ...	=Jupiter	Bluish	1·5 second .	From ι to β Ceti..
5	10 18 p.m	Royal Observatory, Greenwich	Very bright .	Bluish white	About 1 sec	From altitude 4° N., 68° W. to altitude 3° N., 78° W.
28	Evening ..	Near Aberdeen, Scotland	Very large	....	....	. ...
Nov. 15	6 30 a m	Leicester	Very brilliant	Reddish .	Quick . .	Shot down to the S E horizon and disappeared not far from Spica.
22	About 10 0 p m	West Dereham.	Brilliant meteor		. .. .	. .. ..
Dec. 9	4 45 p.m	Burnham	Large meteor	.. ..	... . . .	In the south ....

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
...	....	Meteor with strong light casting shadows. Halted and flashed as if at angles on its course, formed a zigzag streak visible for three or four minutes afterwards, which disappeared in form of a ring.	'Nature,' vol xii. p. 460, Sept 23, 1875; other similar accounts in the 'Scotsman.'
... ..	Moving northwards .	Grew gradually larger until it disappeared. Followed in 4 or 5 minutes by the next meteor [For description of the following meteor, see Appendix I.]	J. J. Allinson.
ong course .	Radiant-point of the projected tracks, 348°, ±0°.	Nucleus pear-shaped and uniform in brightness, with flickering tail of sparks; faded out at disappearance, leaving a faint white streak. Light of the meteor intense Detonation loud at Bradford, heard also at Wath and York (?).	The 'Times,' Sept 16, 'Nature,' Sept. 23, 1875, &c. (See Appendix I. of this Report for the real path and other particulars of the meteor.)
....	Course diagonally downwards from east to west	Nucleus of oblong shape ..	J L, Newspaper account; communicated by W. F Denning
.. ..	Fell obliquely as it passed from east to west.	....	H. H. Olver, Id Id
...	....	.. ..	W F Denning
....	....	Nucleus followed by a streaming train; left no streak.	G. L. Tupman. The 'Times,' Oct. 8th, 1875
....	. . . .	In the night of October 28th. Like a huge rocket, leaving numberless sparks on its course.	Communicated by A S Herschel.
....	Directed from some point in Leo.	Vivid meteor; lit up the sky in spite of the glare of the moon	W. S. Franks. The 'Astronomical Register,' Jan. 1876.
. .. .	.... 	It made two descents, and flashed off at an acute angle, as in the sketch.	Communicated by G. J Symons.
....	....	....	Id.

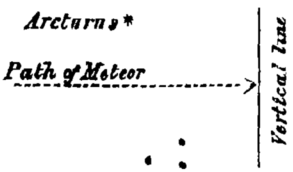
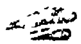
Date.	Hour G. M. T. (or local time)	Place of Observation	Apparent Size.	Colour.	Duration.	Position or Apparent Path.
1875.	h m s					
Dec. 13	10 8 p.m	Bristol	= Jupiter		Very slow	Passed just under β Ursæ Majoris.
22	1 38 p.m	Dorking, Surrey	About ⅛ diameter of the moon	..	Not very rapid	In the N.N.W. ...
22	1 38 45 p.m.	Southampton ..	Large		... .	....
22	About 1 40 p.m.	Braughing, near Ware.	Large	. . ...	..	From W. to N.W., disappearing about 25° above the N.W. horizon.
23	8 44 p.m	Bristol .. .	= Jupiter	....		Passed across μ Geminorum.
1876						
Jan. 4	9 28 p.m.	Street, Somerset	2 × Venus	Yellowish green	1 second ...	α= δ= From 210°+72° to 172 +35
31	9 13 p.m.	Bristol	= Venus	... .	Rather slow .	Path observed, From 64°−12° to 60 −30 In the S.S.W. sky.
Feb. 2	8 31 p.m.	Ibid.	= Mars . . .	.. ..	Very slow speed.	From 175°+31° to 185 +35 on line from δ Leonis to Cor Caroli.
4	7 35 p.m	Ibid.	⅓ apparent diameter of the moon	... . .	Moved very slowly.	From 74°+4° to 50 −1 from γ Orionis to a few degrees below α Ceti.
13	7 8 54 p.m.	Crediton, Devon	Precisely like the planet Venus.	Greenish	....	From β to 3° beyond ε Leporis.

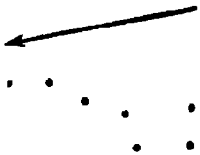
Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference.
....	From direction of the moon Radiant *θ Geminorum.*	Left no streak. On Dec. 19, at $6^h\ 15^m$ P.M., an intense flash, probably of meteoric origin, seen in a clear sky	W. F. Denning. 'Astronomical Register,' Feb 1876.
.. .	From S.S.E to N.N.W, descending thus 	Nucleus an irregular luminous ball, with no well defined disk like the moon; followed by a long train of fire broke up and disappeared before reaching the horizon	H J Powell. The 'Times' and Letter to W. F. Denning.
....	S.W. to N E.	Seen in full sunshine Its form like a common rocket	F W. The 'Times'
About 20°	Inclined about 40° to the horizon.	Shaped like a pear or a kite, left a faint white streak for two or three seconds, and disappeared without exploding Seen in bright sunlight. No detonation heard. The apparent length and inclination of the path were approximately measured with a rod	E Daw. (See also Appendix I for description of the same meteor by Mr Webb)
....	Directed from Polaris Radiant in Draco (about χ Draconis?).	Left no streak...	W F Denning
15°	.. .. 	Cast a strong light. Disappeared behind a cloud.	J. E. Clark.
18°	Radiant A G_1 .... 	Seen through clouds. Left no visible train (Radiant probably just north of α Tauri).	W. F. Denning.
Short path ...	Radiant-point in Leo	Left no streak. This meteor and the next proceeded from the same radiant-point in Leo.	Id.
....	Slightly descending from left to right. Radiant in Leo.	Nucleus globular; left no train...	Id
....	Shot downwards................	Seen on looking away from the planet Venus.	S. J. Johnson. 'Astron. Register,' June 1876, p. 141.

Date	Hour G M T (or local time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path.
1876 Mar 1	h m s 6 46 p m	Bristol	> Jupiter		Slow motion	Passed near ζ and υ Ursæ Majoris or slightly above those stars
19	11 18 p m (Paris time)	Luxembourg Paris	Large meteor			
Apr 15	8 31 p m	Bristol	Much larger though little brighter than Venus	White	2 5 seconds	$\alpha=$ $\delta=$ From 90°+24° to 52 +31 Passed about 5° above ♀, and disappeared behind houses in the W N W
15	About 8 35 p m	Hawkhurst Kent	Very bright			First appeared close to the planet Venus, and streamed past the Pleiades to the horizon
June 15	About 8 10 p m (local time)	Suez and stations on the Suez Canal	Large fireball			
July 8	8 55 p m (local time)	Iowa, U S, America	Large fireball			
20	11 42 0	Bristol	> ♃		Rather swift.	$\alpha=$ $\delta=$ From 337° − 7° to 348 +18
24	10 25 30	Ibid	= ♀		Not very swift	$\alpha=$ $\delta=$ From 306°+27° to 317 +49
24	11 34 0	Ibid	= ♃			$\alpha=$ $\delta=$ From 38°+53° to 55 +39
24	11 37 0	Radcliffe Observatory Oxford	= 1st mag *	White	1 5 second	From 50 Cassiopeiæ (*f* Custodis, Bode) to Capella.
25	About 10 0 p m	Poplar East London	Nearly ½ apparent diameter of the moon 12 or 15 wide but much longer, with no change	Red then vivid green	About 6 seconds Motion quite uniform	From R A 16h 15m S Decl. 17°, to R A 12h 30m N Decl 18° Observed while comet-seeking near the planet Jupiter

Length of Path	Direction or Radiant point	Appearance, Remarks &c	Observer or Reference
Long path	Radiant at α Persei 	Left no streak Seen by F Denning the recorded path from description	W F Denning
		A fireball recorded in the watch for meteors kept at the Observatory of the Luxembourg in March 1876 Mean hourly number of meteors for the month 2 1 ordinary average for the month 5 (	Chapelas Coulvier Gravier Comptes Rendus vol lxxxi p 924
34°	Directed from between Procyon and Castor	Pear shaped nucleus emitting faint sparks as it rolled along left no streak	W F Denning
Course of no great length or speed		A beautiful meteor seen in the western twilight	T Humphrey
		Detonating burst with a loud report	(See Appendix II, Large Meteors)
			Id
20°	Radiant in Aquarius	Very fine meteor left sparks and a train	W F Denning
24°		Left a bright train for 2 seconds	Id
	Radiant in Cassiopeia	Left no streak	Id
		Train [Identical with the last meteor]	J Lucas
		At first small and appeared to be getting red hot then burst forth with a vivid green flame which continued to near the end of its path when it seemed to be burned out and disappeared	John Lane Communicated by W F Denning (See also Appendix II Large Meteors)

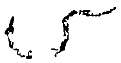
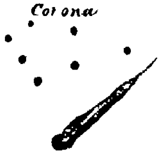
Date.	Hour G. M. T. (or local time)	Place of Observation	Apparent Size.	Colour.	Duration.	Position or Apparent Path
1876 July 25	h m About 10 0 p m	Near Maidenhead, Bucks.	Large meteor .	Vivid green, like an artificial light rather than a natural shooting-star	.. ..	In the northern sky near the Great Bear
25	10 2 p m	Bristol ...	Very large	....	.	Passed from east to north at an altitude[?] above the horizon about the same as that of the planet Jupiter at 9 P.M
25	10 5 p m	Edgeware Road, London	Large apparent disk	Vivid emerald-green; train of fiery red	More than five seconds; leisurely speed.	From the constellation of Aquila [?] through that of Hercules [?]; curved slightly downwards, passing a few degrees under, and disappearing a little northward of Arcturus.
25	10 7 p m	Street, near Glastonbury, Somersetshire	4 × ♃	'Blue' or 'green' (two observers).	About 5 or 6 seconds.	From about 270° −10° to 5° +53° (nearly; view of the stars near its course obstructed by clouds).
25	About 10 12 p m	Hersham, Surrey	Large meteor	.. . .	Speed of apparent motion very leisurely.	Passed close under Arcturus, as in the sketch.
31	9 43 p m	Bristol .	= Sirius	.. ..	Rather fast .	α= δ= From 284° +10° to 286 −10
Aug. 4	10 17 p.m	Glasgow	Not very large or brilliant	.	4 seconds . .	Passed over the south side of Glasgow.
5	10 12 p.m.	Bristol	= ♃	. .. .	.	α= δ= From 20° +47° to 8 +38
[illegible]	10 39 p m.	Radcliffe Observatory, Oxford	= 1st mag.✶ . ..	Red ...	1 second .. .	Passed η Boötis ...

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer or Reference
.. ..	From west to east	Rocket-like; seen by several persons [An equally large meteor, writes the Paris correspondent of the 'Echo,' July 24 or 25, had recently been seen in Paris —T. Crumplen]	W. Wayte The 'Times,' July 28 1876.
.	Moved horizontally, thus ←	The meteor burst at the end of its flight and left a bright train [The recorded altitude of its apparent course disagrees with that assigned at Street, below, and with other more distant observations of the meteor's track]	Communicated by W. F. Denning.
... . .	Almost horizontal [The early part of the meteor's course here described differs very widely from that assigned to it by other observers in the neighbourhood of London]	Body of the fireball a large spherical head tapering away into a tail of fiery red colour, followed by a luminous track Appeared with sudden brightness, and as it travelled on collapsed suddenly with a bright effulgence, exactly resembling a firework close at hand.	E. Ommanney Letter to Mr Glaisher.
Nearly 90° .	Almost parallel to the horizon	Left a splendid train of fragments redder than the head, two of which were as bright as 3rd mag stars. Disappeared with a sudden flash.	Communicated by J. L. Clark.
About 50° ...	Left to right, nearly horizontal  	Sky very clear, and appearance of the meteor very startling Its head had the appearance of being double—thus, the larger of the two parts above (but this impression may have been a deception):— 	George Dines Letter to Mr. Glaisher.
20°	Radiant Lyra or Draco ..	A fine meteor; left no streak seen through clouds.	W. F. Denning.
. ...	From north to south, angle at 37° [?].	Like a rocket, with an extraordinarily long tail. Travelled in a zigzag or tremulous manner.	James Thomson.
23°	Radiant of Perseids	Left a bright train	W. F. Denning.
[illegible]........	Directed about from a Canum Venaticorum [?].	Train. [Identical with the next meteor.]	J. Lucas.

Date	Hour G. M. T. (or local time)	Place of Observation	Apparent Size.	Colour	Duration.	Position or Apparent Path.
1876 Aug. 5	h m 10 40 p.m.	Bristol .	= ♃		Rather swift	From ζ Ursæ Majoris to η Bootis (199° +54° to 207° +19°).
8	11 57 p.m.	Ibid	= ♃	. . .	Not very swift	From 6° + 25° to 356° + 39°, just to left of α Andromedæ
10	About 9 28 p.m.	Ibid	= ♃	... .	Rather rapid .	α = δ = From 53°+79° to 214 +74
10	About 9 54 p.m.	Ibid	Very large meteor; 2× ♀.	...	. . ..	From 85°+78° to 183 +68 (observed path).
10	About 8 30 p.m. (local time.)	Off New York Long. about 54½° W., Lat. about 42½° N.	Like a planet, or brighter	. . .. .	. .....	In the west . ...
11	12 59 a.m.	Bristol	Nearly = ♃	..	. .....	From β Arietis to 2° below the moon, or from 27°+20° to 23° +11°.
11	10 38 p.m.	Bristol	= ♃	...	. ...	α = δ = From 151°+69° to 170 +58
11	About 11 15 p.m.	Cardiff, South Wales	Large and bright .	.. .. .	. .. .	Burst forth over head and travelled in a westerly direction.
11	About 11 20 p.m.	Clifton (and Bristol)	Very large meteor	.. . .	....	....  Apparent course thus, above Ursa Major. (From slightly below Polaris towards the W.S.W. horizon.—Another description.)

Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c	Observer or Reference.
35°	Radiant in Perseus or Cassiopeia.	A splendid meteor	W. F. Denning.
16°	Moved upwards . .	Left a bright train	Id
27°	. ...	Left a bright train for 2 seconds	Id
......	... .	Left a short bright train at 150°+78° visible for 5½ minutes, and drifting thence to 183°+7°.	Id
....	N. to S., in a line nearly parallel to the horizon	From 8h 15m, eight meteors seen; 9h to 10h, 14 meteors; 10h to 10h 30m, 3 meteors. On the 11th, 8h 45m to 9h, 8 meteors; 9h to 10h, 8 meteors seen Aug. 12th, 8h 30m to 10h, only 2 meteors. Sky quite clear most of the time of observation.	Communicated by J. L. Clark.
10°	.. ..	.. . .	W. F. Denning.
10°	Radiant in Cassiopeia	Very fine meteor; left a streak..	Id
....	.. ..	Rocket-like; caused a brilliant flash of light, and left a vivid streak on about 10° of its course, which remained visible several minutes.	C. J. ('Western Daily Times')
. .. .. .	Perseïd...	Extremely bright, like vivid lightning, even in the strong moonlight. Left a broad bright train visible for fully a minute. (Nucleus round or oval. Keynish, near Bristol another, rather smaller, visible ten minutes later. See Appendix II., Large Meteors.)	Communicated by W. F. Denning, from accounts by G. F. Burder, Clifton (and by other observers near Bristol).

Date	Hour G M T (or local time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1876 Aug 11	h m s 11 21 p m	Sunderland Durham	Large and bright	White Streak red above yellow at lowest point		Point of disappearance $\alpha=$ $\delta=$ 281°−21½°
11	11 22 30 p m	Crediton North Devon	Fully as bright as Venus appears at her brightest	Greenish white		First appeared between the constellations Perseus and Ursa Major From 10 (β d_1 Bode) Camelopardi, halfway towards α Ursæ Majoris
11	About 11 24 p m	Writtle near Chelmsford Essex	Much brighter than Ve			First appeared about 6° north, preceding α Coronæ passed between that star and ε Bootis, and died out a few degrees S W of α Coronæ
13	9 27 p m	Radcliffe Observatory, Oxford	Large meteor			Starting point near α Cassiopeiæ End of course hidden by the Tower of the Observatory
13	9 27 p m	Buntingford, Herts	= ♀		At least 2 secs Moderate speed	Passed close to α Cygni About $\alpha=$ $\delta=$ from 30°+67° to 305 +37
15	About 9 26 p m	Bristol	At least as bright as Venus appears at its maximum		Slow motion	First seen slightly above Arcturus; disappeared under the star group of Comæ Berenices, on the N W horizon, descending obliquely
15	9 30 p m	Radcliffe Observatory, Oxford	3 or 4 × Jupiter	Blue to green	4 seconds	From α, passing η Bootis, to a point on the horizon in a line with η Ursæ Majoris and α Canum Venaticorum

Length of Path.	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference.
Terminal part 2° or 3°.)	Directed from η Aquilæ.......	End of course only seen, disappearing behind trees, with a strong glow extending many degrees round Streak 2° long left for three seconds, 1° or 2° above the point of disappearance.	T. W. Backhouse.
....	Form of the streak. 	Left a streak visible for 50 seconds, which became curved like a reaping-hook before disappearing. Also seen at Lytham (coast of Lancashire), at 11h 18m P.M., apparent path near the zenith and to the southward	S J Johnson. ('Exeter & Plymouth Gazette.')
....	.... 	Meteor like a long pale-green flash, leaving an orange train for fully a minute.	H Corder ('Astronomical Register,' Sept. 1876)
	Shot southwards	Left a long train. [For a description of this meteor's course at Folkestone, see Appendix III., Periodic Meteor-showers]	Communicated by J. Lucas.
5°	....	A fine Perseid, left a streak for 5 or 6 seconds [Identical with the last meteor.]	R. P. Greg
....	Not a Perseid; radiant apparently in Aquila.	Nucleus pear-shaped, emitting sparks as it rolled along, but leaving no persistent streak visible in the hazy sky.	W. F. Denning.
....	....	....	J. Lucas.

APPENDIX.

I. METEORS DOUBLY OBSERVED.

In the list of observations presented with last year's Report, several examples of meteors doubly observed, chiefly in the August meteor-shower in 1874, occurred, and the heights and real paths of these meteors have been calculated. The computed real paths and velocities, and the radiant-points from which the meteors were directed, are shown in the Table opposite.

It is probable that few observations are sufficiently trustworthy to give correct values of the speeds of individual meteors, but among several such determinations the average velocity of the Perseids here found may be regarded as approximately ascertained, and it does not greatly exceed the value which theory assigns to it. The real path and radiant-point of the fireball of August 10th, 1874, has been recalculated, as well as the velocity from the average of two observed durations of its flight, the calculated speed is within a mile of the velocity of a body moving in a parabolic orbit from the direction of the radiant determined by its apparent paths. The latter point is very near a known radiant-point of a shower to which it may be presumed that this large fireball belonged, and a marked centre of radiation of shooting-stars near μ ε Aquarii, during the annual shower of Perseids, is thus probably confirmed by this double observation. The recorded tracks of the fireball at Birmingham and Newcastle-on-Tyne diverge from a centre at R.A. 313°, S. Decl. 14°, and a radiant-point from the 3rd to the 31st of August is shown by Dr. Schmidt's investigations to be observable at R.A. 306° S. Decl. 8°. The star ε Aquarii (R.A. 310°, S. Decl. 10°), near this, at some distance from which several other radiant-points for July and August are clustered in Aquarius, occupies the extreme west, while the latter radiants more nearly adjoin a star θ (R.A. 333°, S. Decl. 8°) which is in the eastern part of the same constellation *.

In the list of large meteors which accompanies this Report, an observation of a large fireball on August 16th, 1875, at 10^{h} 26^{m} P.M., near St. Agnes, Cornwall, is described, of which two other descriptions also appeared in 'The Times' of August 21st and 25th, showing that the meteor was visible over a very wide area, from Wales to Brittany in France.

Ty Mawr, Ty Llangelly, near Crickhowell; Mr. H. Ball.—"On August 16th, at 10^{h} 26^{m} P.M., I saw a very bright meteor, which is probably the same as that seen by your correspondent F.R.S., from St. Agnes, Cornwall. From this place its position was nearly 5° below and to the right of the full moon, on a line inclined 45° to the horizon."

Redon, Lower Brittany, France, F.R.G.S.—"It may be worth while mentioning that the meteor seen in Cornwall and Wales was also seen by me at Redon, Lower Brittany, at the same time. It was exceedingly brilliant, and, as F.R.S. remarked, it much resembled a string of magnesium beads. The night was singularly clear and the moon very bright, but the

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* In the copy of Schmidt's list of radiant-points printed in the volume of these Reports for 1874, p. 321, it should have been observed that the positions to which *days* as well as months of duration are assigned are asterisked in the original list as accurately (the rest being less accurately) determined. The radiants near θ Aquarii in Schmidt's and Tupman's lists are erroneously quoted in the Monthly Notices of the Royal Astronomical Society (vol. xxxvi. p. 218) as being the "nearest known" radiants to the above described point of emanation of this meteor's real course.

Real Heights and Velocities of Shooting stars and of a Bolide observed in England, August 10th and 11th, 1874

Ref No	Date. 1874 Aug	Hour approx. G M T	Place of Observation.	Magnitude Colour Duration	Position of Apparent Path From To α δ α δ	Appearance Streak Remarks Observer	Meteor's Real Course				Length of Path	Velocity Miles per second	Radiant point, α δ and Remarks.
							Began		Ended				
							Height in E S miles	Geographical Position	Height in E S miles	Geographical Position			
	d	h m s											
1	10	10 52 15	Newcastle-on Tyne	>1st mag or yel 1 5 sec	From 5° before δ Equulei shot across that star to λ Normæ Aquarii	30° streak 3 secs A S Herschel	99	Over a point 3 miles S of Castle Howard Yorkshire	63	Over Mitford Yorkshire	41	41 (average) 27 3 Newcastle)	15° +59° (γ Cassiop) A fair accordance.
1	10	10 55 30	York.	>1st mag 0 5 sec	330° +57° 300°,+47°	15° streak J E Clark							
2.	10	10 52 45	Newcastle-on Tyne	>1st mag or yel 1 5 sec	From 2° below ε Pegasi to 4° below μ Aquarii	Streak 3 secs. A S Herschel	80	Over a point 3 miles S W of Driffield Junction Yorkshire	64	Over a point 4 mile W of Ledsworth Yorkshire	41	37 (average 23 (Newcastle)	51 +56 (D Camelop) A fair accordance
2	10	10 55 30	York.	= ♃ 0 7 sec	333 +50 316 +38	16° magnificent streak 8 secs J E Clark							
3	10	11 5	Newcastle-on Tyne	1st mag or yel	Passed across α [? β] Aquarii directed from ⅓ (β μ) Pegasi.	Streak 2 secs A S Herschel	79 [? 99]	Over a point 2 miles W [5 miles E] of Shipsar Yorkshire	58 [53]	Over a point 4 miles E of Selby [? 4 miles N of Doncaster] Yorkshire	0 [68]	0 [68]	7 +54 [? 24 +54] Newcastle observation doubtful should perhaps be β
3.	10	11 8	York	= ♃ 1 sec	350 +51 307 +27	33° streak J E Clark.							
4.	10	11 27	Newcastle-	= Sirius white, 1 5 sec	From 5° before ε Cygni to 5° beyond ⅓ (β Delphini α Aquilæ)	Streak 4½ secs A S Herschel	91	Over a point 4 miles W of Darlington Yorkshire	43	Over a point midway between Leyburn and Kettlewell Yorkshire	53	53 (average) 35 3 (Newcastle)	352 +72 (Polarid) Good accordance of apparent paths.
4.	10	11 30	York	= ♀ yel. to red 0 5 sec	261 +68 236 +41	28° streak 2 secs J E Clark							
5	10	11 32 15	Newcastle-on Tyne.	>Sirius white 1 5 sec	From ⅓ (δ d) Lacertæ to ε Delphini	40° streak on whole course brightest in mid of course 8 secs A S Herschel	82	Over a point 5 miles W of Hartlepool Durham	43	Over a point 1 mile N of Bedale Yorkshire	51	51 (average) 34 (Newcastle)	37 +64 (ι Cassiop) A very good accordance
5	10	11 34	York	= ♃ 0 5 sec	260 +80 250 +65	17° streak 4 secs J E Clark							
6	10	11 34	Sunderland	2nd mag	In Cygnus	Conformable T W Backhouse							Sunderland observation only approximate
6	10	11 36	York	1st mag 0 25 sec	253 +79 235 +71	10° streak 1 sec J E Clark							
7	10	11 53	Birmingham	1st then elongated (⅔ × ½ D) bl wh then red 6 secs	260 +18 216 +32	Expanded & burst near Corona thence as 1st mag star with deflected course to ε Bootis W H Wood	66	Over a point 6 miles N E of Pencader Caermarthenshire South Wales	33	Over Bangor N Wales	85	113 (average)	313 −14 5 Near μ e Aquarii) Agreement of apparent paths very exact
7	10	11 53 50	Newcastle-on Tyne	= ♀ orange then green with red sparks 2 8 secs	287 −17 275 −17	12° expanded leaving fragments and red sparks on track to extinction in streak A S Herschel							
8	10	12 6	Birmingham	2nd mag blue 0 5 sec	176 +75 190 +62	Radiant η Persei W H Wood	97	Over Beckwith West Riding Yorkshire	3	Over Chipping Lancashire	54	45 (average) 34 (Newcastle)	38 +59 (Cassiopeid) Fairly good accordance
8	10	12 7	Newcastle-on Tyne	2nd mag yel. 1 sec	From ζ Cygni to 3° preceding ε Delphini	Streak 2 secs A S Herschel							
9	11	10 41	Birmingham	1st mag yel 1 sec.	33 +66 27 +72	W H Wood	68	Over a point 2 miles N of Tuxford Notts	5	Over a point 2 miles S of Alfreton Derbyshire	28	32 average Birmingham)	30 +49 (θ Persei) A good agreement Observations all independent
	11	10 41	Ibid	1st mag yel 0·75 sec	32 +65 25 +70	T H Waller							
9	11	10 43	Tooting Surrey	1 2 mag white	157 +62 165 +57	Close to α β Urs Maj H W Jackson							
10	11	11 30	Birmingham	2nd mag 0·75 sec	46 +62 4 +6	T H Waller	7	Over a point ? miles S E of Moortown Lincolnshire	59	Over a point 3 miles N E of Carlton Notts	32	43	49 + 3 (D Camelop) Agreement not so close as the last
10	11	11 30	Tooting Surrey	1 2 mag white	142,+67 157 +62	Ended close to where the last began H W Jackson							
Average Heights &c (omitting the Bolide No 7)							84		55		41	44	
Average Velocity (from Newcastle observations of durations) of four Perseids and Cassiopeids and one Polarid												31 5	

light of the meteor was very striking; it appeared to me to be moving slowly in a comparatively horizontal course."

The most important instances when duplicate observations of meteors were collected during the past year, permitting the height and direction of the meteors' real paths to be determined and very accurate results to be obtained, occurred on the 3rd, 7th, and 14th of September, 1875. It would occupy too large a space in these Reports to relate at length the various accounts that were published of these meteors; and those which offered the greatest accuracy of description and position only are here extracted from the comparison and reduction of a great many excellent records of their appearance published by Captain Tupman in the 'Astronomical Register' for April 1876.

Meteor of September 3rd, 1875, $9^h 52^m$ P.M.—A meteor ending with a flash almost as blinding as the sun, seen by G. L. Tupman at the Royal Observatory, Greenwich, with an apparent diameter of about 15′ of arc, falling exactly vertically in 1½ or 2 seconds to a point less than 1° below and rather less than this to the left of κ Aquilæ, from a distance of some 20° above that point. It diminished in brightness at first, but disappeared with a flash at last, having about half the moon's apparent diameter, as far as its brilliancy allowed the eye to estimate apparent dimensions of its disk, and it appeared globular and left no streak on its course.

This is the description given of it by Captain Tupman, and similar accounts of its path and appearance were obtained at other places. At Tedstone Delamere Rectory, near Worcester, it was visible in the S.E. by S. falling vertically, and also falling vertically at the Radcliffe Observatory, Oxford, by Mr. Lucas; while at Leighton Buzzard the direction of its path was also vertically downwards, and its appearance at all these places was extremely brilliant. The radiant-point of this meteor was very nearly in the zenith at the time of its appearance, and from the positions of its apparent course furnished by the different observers, Captain Tupman concluded approximately its real course, as will be seen in the annexed Table (p. 144) of the real paths of this large meteor and of two other brilliant fireballs which appeared a few days later in the same month*.

The second large meteor generally observed in the southern parts of England in the first week of the same month appeared at $11^h 21^m$ P.M., September 7th, 1876; and eight or nine reliable observations of its apparent course at different places, principally in Kent or Surrey, and Essex, and at Ipswich and Oxford, were collected and compared together by Captain Tupman. Among these are descriptions by the observers at the Royal Observatory, Greenwich, and at the Radcliffe Observatory, Oxford. It appears to have been of somewhat less splendour than the other two bright fireballs of which numerous accounts in the beginning of September were obtained, but yet, as seen from Writtle near Chelmsford, almost immediately below its real point of disappearance, it will be seen, from Mr. H. Corder's excellent description of it† which follows, that its light was sufficient to illuminate all objects with a bright flash, and that a very distinctly audible detonation followed its disappearance.

"I did not see it at first, but heard that it rose upwards from the S.W.

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* The details of the various descriptions, and a valuable series of conclusions and deductions from them, will be found in an article communicated by Captain Tupman in the 'Astronomical Register' for April 1876. The final results of his calculations of these meteors' real paths are also contained in the number for February, 1876, of the 'Monthly Notices' of the Astronomical Society, vol. xxxvi. p. 216.

† 'Astronomical Register' for October 1875, vol. xiii. p. 246.

[? S.E.], bursting like a skyrocket into a number of pieces, then fading away and bursting out again. At first it was of a blue colour. It was sufficiently brilliant to light up the country When I saw it it had just passed above α Andromedæ, and was of a decided mauve tint and double. It rushed along at a great speed, with an unsteady flickering light of great brilliancy, and disappeared near the cluster [χ] in Perseus It left no train, but was followed by a few sparks One minute and three quarters after disruption I heard a double explosion like the firing of a double-barrelled gun at a distance, followed for about 15 seconds by a rolling sound like distant thunder I also heard that on the Friday previous (the 3rd of September) a bright meteor was seen, just before 10 P.M., bursting into several red sparks. It went about in a direction N. to S."

Another well-described account of the magnitude and appearance of the bolide of September 7th is that of Mr. W. A. Schultz, who saw it at Lewisham (near London), Kent, and writes that it appeared to be three times the apparent size of the planet Jupiter, of bluish-white colour, leaving a fine train. The nucleus was of extreme brilliancy, and emitted magnificent blue and red sparks Its duration was 1½ second. From Mr. Corder's account near Chelmsford it appears that the fireball detonated, or broke up and disappeared with an audible explosion, the sound of which occupied 1¾ minute in reaching his position. This being, according to the calculated real place of the meteor at disappearance (21 miles above a point near Witham in Essex), about 23 miles distant from his place of observation (a distance which sound takes 1^m 50^s to travel at its ordinary speed in air), it affords a satisfactory ground for the conclusion that this fireball, although not so brilliant as that which preceded it on September 3rd, was yet certainly of the detonating or "aerolitic" class, which was also the character of the fireball of 14th September, to be next described

This was one of the largest meteors which has been visible in England for several years, and numerous notices of it were published in the daily newspapers, in addition to which several private accounts of its appearance were collected by the Committee, and more particularly by Captain Tupman, who himself observed the meteor, and who has compared together all the available descriptions. Omitting details of the apparent positions of the meteor's path by the stars, which have been recorded and carefully reduced by Captain Tupman in the above-mentioned communication in the 'Astronomical Register,' the following are some of the particulars recorded at different places of the meteor's brightness and general appearance.

Near the Royal Observatory, Greenwich, Sept. 14th, 8^h 27½^m, G.M.T., Captain Tupman states —"The fireball was very bright, but of ordinary appearance, three or four times brighter than *Venus*; long train; left no streak; colour white; motion slow and stately. I estimated the duration at two seconds, perhaps more; but I did not count. Lieut. Neate, R.N., saw it from the Observatory grounds, but lost it behind a roof at mid course, after seeing it for two seconds. Colour deep yellow, with red lower edge. Time 8.27 P.M."

Train Inn Station, near Hereford, 8^h 30^m P M.—The Rev. T. J Smith describes the colour as a beautiful greenish blue of intense brightness, even in the strong moonlight. The train narrow and straight, of red sparks, which continued longer than the light of the head. It appeared to extinguish without any detonation.

Near Wisbech, Mr. S. H. Miller writes :—"I was driving towards the west, and the moon shining brightly in a cloudless sky, when my attention was attracted towards the north by the bright light of this beautiful meteor. At first it was as large as Venus three times magnified, and of a blue colour. In about a second it passed into the pear-shape, leaving a thin streak behind it. [The appearance of a fireball seen at Wisbech on March 4th, 1872 (see these Reports for 1872, p. 76), "like a drop of molten silver," is here referred to by Mr. Miller as exactly resembling the aspect which this fireball assumed at its greatest brightness.] In another second it diminished to the size of a star of third magnitude and appeared yellow. There was no explosion, but it disappeared about 15° from the horizon."

Other descriptions at Teignmouth, Wath near Rotherham, Halstead in Essex, Faringdon in Berks, York, Ludlow, Bath, Cambridge, and Manchester agree in describing the luminous appearance of sparks, corruscations, and light flakes accompanying the meteor as confined to a short flaming and flickering tail, sometimes divided, following the head, somewhat redder than the foremost brightest part, which had an apparent width of ½ or ¾, while the whole apparent length of the oval disk of the meteor was fully equal to or somewhat surpassed one lunar diameter, and the nucleus collapsed on nearing the horizon without any signs of an explosion. Some portions of the train of sparks appear to have been of more persistency than the rest, as an observer at Sudbury, Suffolk, writes:—"The shooting-star itself was very large and bright, and attached was a long tail, broken at about a third of its length from the end into dashes and dots of bright colours, leaving a white track behind for several seconds after the meteor itself had disappeared." The accounts at other places describe a flame-like tail and sparks following the head, although not a persistent light-streak left upon the meteor's course. An observer at Duxford, near Cambridge, saw not only the meteor but the sparks also *through* an ordinary white calico window-blind, which was *down* at the time.

As regards the meteor's brightness, its light at some points of observation fully equalled and perhaps surpassed the intensity of full moonlight. In a letter to Mr. Glaisher, an observer at St. Ives, Hunts, Mr. J. King Watts, relates that the meteor "started into view from Ursa Major immediately opposite the moon, it travelled slowly, was of the most intense bright white light, round, and five or six times the size of any of the planets. The sky was clear and cloudless. We were travelling between the moon and the meteor, and our shadows on the road caused by the moon were of course large and clear, but those caused by the meteor were more clear and more sharply defined." A notice of no less interest and importance (but with which no name and locality were given) appeared in the 'Northumberland Daily Express,' affording good proof of the intensity and duration of the meteor's light. "There was a tree in the passage; and suddenly I found myself surrounded by a wonderfully bright light, and the shadow of the tree was cast on the wall on my left, every leaf and twig more distinctly than in the sunshine." Believing the light to proceed from a window in the house, and perceiving it to come from beyond the house, the observer stepped back a few paces to the corner, and was just in time to see a most brilliant meteor descending towards the earth. "It did not burst or explode in any way, but gradually diminished till it became extinct" The glare of the meteor's light on the ground, already strongly lighted up by the moon, attracted Mr. J. W. Proctor's attention to it when driving north-westwards from Grimstone towards York; and an observer near Carlisle, driving southwards to that town from Longtown, describes the meteor's appearance thus:—"At 8h 25m a meteor of most dazzling brightness caught my eye. I saw it first apparently in close proximity to the full moon, which by the side of the meteor appeared quite pale. In colour it was not unlike a Roman candle [white or blue]. It moved very slowly through the sky, in a direction westwards and downwards." [The direction assumed in the calculations is towards the point iv^{h} or 20^{m} indicated by the hands of a clock, having the moon at the centre of the dial.]

The earth-point of this meteor, as concluded from the observations by Captain Tupman, or the place where the meteor's real path prolonged would have reached the ground, is in the neighbourhood of Sedburgh, a town in the extreme north-west part of Yorkshire, and not far south-south-eastwards from Carlisle. The point of disappearance was at a height of only 13 or 14 miles above the earth's surface, not far from Pately Bridge, West Riding, Yorkshire. The distance of this latter point from Wath, near Rotherham, is about 47 miles, which sound would traverse, with its ordinary speed in air, in about $3^{m}\ 47^{s}$. Mr. W. M. Burman, who saw and describes the meteor as it appeared at this place, heard a detonation which, from its close agreement with the calculated time required by the sound of the meteor's disruption at disappearance to reach him, was probably a distinctly audible sound of its explosion. He writes:—"The magnificent meteor of Tuesday night, Sept. 14th, was well seen here in a cloudless sky at $8^{h}\ 26^{m}$ G.M.T. I was walking, and the full moon was throwing my shadow on the wall on my right, when suddenly a dazzling light shone around, and my shadow vanished from the wall. Upon looking up, I saw this magnificent meteor slowly careering across the sky, quite overpowering the light of the moon. It passed nearly overhead, and disappeared in the N.W. by W. It was of a half-moon shape, the preceding part being convex and sharp, the following part flame-like and flickering, and of a brilliant bluish-white colour. No red tinge was seen from first to last, nor train, nor sparks. Its diameter was about half that of the moon. In that dazzling light it was impossible to see any star; but soon after it had passed I tried to make out its path*. Its total visibility was about 6 seconds, but I only saw it during 4 or 4½ seconds, as it went behind the roof of an adjacent house; but a friend (who saw the end of its course from a neighbouring place) says that it simply disappeared, no sparks being visible, nor any change of colour. Three and a half minutes after it disappeared I heard a sharp and sudden explosion, like the report of a small cannon at a distance, exactly from the direction that the meteor had taken; but whether it had any thing to do with the meteor or not I cannot tell." Mr. Burman adds that "the rumbling of a distant train prevented me from hearing any sound during the passage of the meteor, if any such were audible;" and it was, in fact, remarked by several who described the meteor, that while it was in sight a rushing or hissing sound accompanied its passage through the air. Passing over these descriptions as impressions of very doubtful positive reality, the case of such a sound recorded at York by Mr. Proctor may perhaps be explained as due to a real detonation, of which he gives the following description at that place:—"I have some impression that it was accompanied or followed by a rushing sound, and a friend of mine thought the same, but amounting to an explosion at a great distance." In a note of some length in 'Nature' (vol. xii. p. 460) on large meteors in the early part of September, 1875, particulars of the appearance of that of September 14th as seen at Bradford are extracted from the 'Bradford Observer' of September 15th, where it is related that "to a spectator it bore the appearance of some solid body in a state of combustion, the sparks flying out on all sides, and a track of flame being left after its passage. Its passage was accompanied by a noise as of a loud explosion, which was plainly heard, not only by those who were outside, but by persons inside the houses who did not see the aerolite itself. All parties concur in saying that so strong a light was cast around that a newspaper could easily be read for the space of half a minute."

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* Mr. Burman's position, so nearly under the brightest portion of the meteor's track, may have led to its extreme brightness hiding and overpowering the sparks and duller fragments which, at more distant stations, are said to have attended and followed the meteor in some part of its course as a train of redder colour than the head.

It should be remarked as a curious coincidence, not unfrequently recorded in the accounts of large meteors, that a companion fireball of the brilliant meteor of September 14th was noticed by one observer of its appearance. Mr J. J. Allinson, at Lynn, Norfolk, states that "at $8^h\ 20^m$ P.M., the moon shining brilliantly in a cloudless and clear sky, I saw very low down in the eastern heavens a bright meteor of a bluish colour, three or four times the size and two or three times the brightness of Venus at her largest and brightest. The bearing was about E. by N, and it seemed moving in a northerly direction, but, by its getting larger, to be approaching the spot where I was standing. I should say it disappeared before reaching the horizon. [There is little doubt, Captain Tupman observes, that this meteor belonged to the same meteor-system as the much larger companion fireball by which it was shortly followed.] About 4 or 5 minutes afterwards, whilst looking in a south-westerly direction, I was attracted by a bright light in the north-western sky, and on looking towards that quarter observed a most splendid meteor, about the size and colour of the first, but much more brilliant, descending from near the last star [η] in the tail of the Great Bear in an almost vertical, but I should say somewhat irregular course." Of the former of these two fireballs no corresponding observations (as it must have been seen over distant parts of the North Sea or over Belgium) from other places have hitherto been obtained; but from its central position over the midland and northern counties of England, observations of the second extremely bright meteor of the pair were recorded abundantly at all stations throughout the country, as has been described, from its interest and importance, in the foregoing paragraphs at considerable length.

Both this large fireball and that which preceded it on Sept. 7th may be presumed from these descriptions to have been "aerolitic" or detonating ones; and it is remarkable that they had nearly a common radiant-point, and that this point of divergence or real direction of the two meteors' flights is in close agreement with well-established radiant-points of shooting-stars in the first half of September, to which the observations of Heis and Schmidt, and the meteor-shower lists of Greg and Tupman, all agree in assigning very nearly corresponding places and durations. The following Table, p 144 (from the 'Monthly Notices' of the Astronomical Society *sup. cit.*), describes the results of calculation from observations of these three large meteors; and the closing words of his communication to the 'Astronomical Register' (from which the foregoing particulars are extracted) will here describe the astronomical determinations obtained by Captain Tupman as regards the actual orbits and the probable known showers or systems of ordinary shooting-stars to which the last two detonating fireballs of these three bright September meteors may, in all probability, be conjectured to have belonged.

Heights and Real Paths of large September Meteors, 1875 *By* Captain TUPMAN

Date.	G M T	Weight or degree of accuracy	Radiant-point.		Height and Position of Real Path at		Length of Path Duration and Velocity Statute miles per sec.	Nearest known Meteor Radiant point
			R.A.	Decl.	First appearance	Disappearance		
1875 Sept. 3	h m s 9 52 0 P.M.	From three accordant observations.	311° (near χ Cephei)	+52°	(Statute Miles) Fell vertically from 75 to 40 (±1) miles above a point 14 miles S S E of Selsey Bill on the Sussex coast 50° 31 N 0° 57 W		About 20 miles per second (approximate conjectural value from two observations)	S & Z. No 146 Sept 5 321° +60°
„ 7	11 21 0 P.M.	From six accordant and two discordant observations.	344° (near α Pegasi) A second independent reduction gave 347°	+14° +15° ± 2°	82 miles over mid point between Ashford and Hythe, Kent, and thence 67 miles above Faversham Kent (Writtle observation)	22 miles above a point 5 miles S S E of Witham	18 miles per second (average of four least discordant observations probable error ±5 miles)	Tupman, No 73 Sept 7 15 345° +13° Heis, T. Sept 1 15 343° +10°
„ 14	8 27 30 P.M.	From twelve (8 of which are good) accordant observations.	348° (Near γ Piscium)	0° (±2°)	63 miles over Hindringham Norfolk (52° 53 N 0° 56 E)	14 miles over Hebden Moor West Riding Yorkshire (54° 3 N 1° 53 5 W)	121 miles in 8 seconds (mean of nine estimates of duration) Velocity 15 miles per second certainly a close approximation	Schmidt Sept. 3–14 346° +3° and Sept 344°, −3°

Regarding the second, which, like the last of these meteors, was probably aerolitic, Captain Tupman observes.—"It had two heads, one close behind the other, or it divided itself at mid course, the two parts slowly increasing their distance apart by retardation of the hindermost as they rushed through some 50 miles in something under 3 seconds of time. This appears to be a proof of sensible retardation by the density of the atmosphere, although its pressure could hardly have exceeded two tenths of an inch of mercury. Had the meteor remained in existence another second it would have fallen into the village of Castle Hedingham, 5 miles S.W. of Sudbury The heated matter left behind it in the form of a tail was visible along 10 or 15 miles of its path"[*]. On the resemblance of the orbit of the last of the three meteors to that of the second, the following considerations are also adduced—"The astronomical radiant-point is within 15°, probably within 10° of that of the meteor of Sept. 7th The two meteors were also similar in character, and they appear to have moved with nearly equal velocity, something under 20 miles a second. This part of the heavens has also been known for many years as a radiant-region for shooting-stars at this period of the year.

"Dr Heis found for September .	343°	+10°	
Messrs Greg and Herschel, September	344	+12	
Dr Schmidt, Sept 3-14 .	346	+ 3	345° ±0°
" Sept	344	− 3	
Tupman, 1871, Sept 3-15 ..	345	+13	

"The mean of the two found by Schmidt is within 3° of the Sept. 14 fireball radiant, and the mean of the other three is as close to the Sept. 7 radiant. The old positions, therefore, receive a genuine and unexpected confirmation from these two fireballs, the radiants obtained for which are certainly quite as accurate as the others, and merit being classed as new determinations"

An interesting notice (as observed above) of the remarkable fireballs of the first two weeks in September appeared in 'Nature' of Sept. 23rd, 1875 (vol. xii. p. 460), in the course of which some particulars similar to those related above of the appearances of these splendid meteors are described.

Among the few accurate descriptions which were obtained of the large daylight fireball of the 22nd of December, 1875, the accounts of its appearance by observers at Dorking, at Southampton, and near Ware are included in the list of large meteors accompanying this Report. The following observation of it by Mr. T. W. Webb ('Nature,' vol. xii. p. 187) furnishes some further extremely valuable notes of its apparent course.

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[*] It should be observed that in his investigations of the stonefall of Pultusk (Jan. 30, 1868) it was shown by Galle that the area upon which the stones fell was vertically below the point of the fireball's disappearance (twenty miles above the earth), and not, as might have been anticipated, in the line of the meteor's obliquely descending course prolonged onwards from that point to meet the earth's surface A drawing of the fireball of September 7, 1875, from a sketch at the time, was recently communicated to the Committee by Mr. H Corder, representing his view of the meteor in the end part of its course, which he observed After a bright disruption into several pieces (seen by other observers), two large nuclei were visible, not following each other, but moving side by side, equally bright and tapering, and one of them about half a length in advance of the other, with a clear interval of about one diameter of each between them A very small fragment was also visible, which disappeared quickly, while the two heads continued their course, with scarcely any changes of brightness or of relative position, from near α Andromedæ to near χ Persei, where they died out rather suddenly, leaving no streaks, almost together The sound came from the S E., where the meteor burst, not from the east, where it died away, and persons who saw it before the disruption said that the meteor was then a single body.

Hay, S. Wales.—"Dec. 22. As our servants were sitting at dinner by the kitchen window, two of them were startled by the sudden appearance of a brilliant meteor, apparently descending in the east, with a little inclination to north. It was not so large as the moon, but much larger than Saturn or Mars; white and like lightning, with a very quick course, leaving a train as broad as itself, and preserving its full size till lost behind the top of an oak tree at a little distance, whose branches, though leafless, seem to have concealed it from view. The next day I found, by means of a compass and joined ruler, that its azimuth was E. by N., its inclination towards north about 10°; the upper window-frame, where it probably came in sight, 48°, and the top of the tree about 18° above the horizon. I have not as yet heard of any other observation of this remarkable meteor. The position of Hardwicke Vicarage, where it was seen, according to the Ordnance Map is long. W. 3° 4′ 23″, lat. N. 52° 5′ 20″."

A comparison of this account with the observation at Braughing by Mr. Daw affords a rough determination of the real path and direction and of the probable place and altitude of this unusually bright meteor's course above the earth's surface, but owing to the absence of estimates of the duration of its flight, no probable value of the meteor's real velocity can be assigned. The course of this daylight meteor appears to have been from about 45 miles above the southern part of Warwickshire to about 15 miles above the centre of Northamptonshire, disappearing about 50 miles from Mr. Daw's position near Ware, in Herts, where he states that no sound of an explosion following its appearance could be perceived. The direction of its flight was from a radiant-point at about R A. 250°, N decl. 20° (near β Herculis), distant about 45° above and westward from the apparent place of the mid-winter sun, which was shining brightly above the southern horizon when the meteor came in sight*.

The bright meteor seen in twilight on April 15th, 1876, at Bristol and Hawkhurst (see the accompanying fireball-list), must have passed over Ireland or the Irish Channel far west from Bristol, as the position of its apparent path there, near the setting planet Venus, differed very little from the similar account of its apparent path in Kent. The position of its radiant-point cannot have been the usual one in Virgo (about 196°, ±0) in the early part of April, as its recorded path at Bristol, prolonged backwards nearly parallel to the ecliptic, crosses the constellation Virgo about 20° south of the equator in the neighbourhood of this position, proceeding from the direction of a region where no well-established radiant-point of ordinary shooting-stars has hitherto been observed.

The next large meteor, of which many contemporaneous observations were communicated to the Committee, some of which have also appeared in the daily newspapers, was that of July 25, 1876, about $10^h\ 5^m$ P.M. Several accounts of this fireball are contained in the list of large meteors accompanying this Report. It resembled the fireball of September 14th, 1875, in appearance, excepting that a decided green hue of the nucleus was observed, and a somewhat more voluminous train of red sparks and fragments appears to have followed the head. The light which it cast was not so intense as that of the fireball of September 14, and no sound of a detonation is related to have been perceived. The radiant-point of this large fireball was near Antares; but, owing to its recent appearance, the descriptions of it hitherto collected have not been submitted to exact calculation, although some of those recorded in the present list are sufficient to determine with considerable accuracy its real path.

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* 'Monthly Notices' of the Royal Astronomical Society, vol. xxxvi. p 217. Mr. Daw's place of observation, given as "Brangling" in that account, should have been Braughing, near Ware, in Herts

From the following descriptions it appears probable that a companion meteor may also have been visible, corresponding nearly in the time of its appearance with the principal large fireball which was generally observed. Mr. John Lane, whose very exact observation of the meteor at Poplar, London, is included in the list, remarks:—"It appears to me there must have been two meteors seen near the same time, one sea-green and very large [the meteor of $10^h 5^m$ P.M., July 25], the other purple and somewhat smaller. The clear observation and description given by Mr. H. Pratt from Brighton I cannot harmonize with *my own*, while some others agree very well with it. My results are that it began vertically over a point in W. long. 1°, N. lat. 50° 10′, and ended over W. long. 2° 15′, N. lat 51° 43′, at an elevation of about 34 miles. Distance travelled in relation to the earth 120 miles, in the orbit of the meteor 170 miles. Actual diameter about 500 yards."

The following duplicate observation of a shooting-star from the direction of α Lyræ on the date of this large meteor's appearance was obtained (as the Committee was informed by Mr. Denning) from a comparison of his own observations at Bristol with those made by Mr. Clark on that date at Street, near Glastonbury, about 20 miles south-south-westwards from his point of observation.

Ashley Down, Bristol (W. F. Denning)	1876, July 25, $10^h 55^m$ P.M.	= 1st mag. star	Rapid, Radt. near α Lyræ	From 276°, +4° to 275°, −5°	9° length of path
Street, near Glastonbury, Somersetshire (J. E. Clark)	1876, July 25, $10^h 55^m$ P.M.	= 1st mag star	1¼ sec Directed straight from Vega.	From 280°, +22° to 280°, ±0°	22° length of path

Another large fireball, apparently a Perseid, was very generally seen and recorded in the southern counties of England at about $11^h 23^m$ P.M. on the 11th of August, 1876, several descriptions of which are included in the accompanying fireball list. Of this bright meteor (which had a long course and possessed great illuminating power, and which left a persistent streak visible for about a minute, becoming curved or serpentine before it disappeared) the real path derivable from the observations hitherto collected has not yet been computed from the few exact observations of it which have been preserved. But of this fireball, and of an equally bright one which appeared at about $9^h 26^m$ P.M. on August 15, sufficiently abundant materials exist to enable their real heights and the true radiant-points or meteor-systems to which they must have belonged to be satisfactorily ascertained. As regards their brightness and appearance, some observations not contained in the above list are here subjoined, for which the Committee is indebted to the active correspondence and communications of Mr. Denning respecting the several bright meteors which have been visible in quick succession during the past month of August.

Keynsham, near Bristol (Mr. H. Marks).—On the 11th of August (1876) I was walking along a valley from about $10^h 45^m$ to $11^h 15^m$ P.M. [the time is a rough approximation], when all at once—I did not notice the star there before—an exceedingly bright star shot from about N.E. close to the horizon to S.W., leaving a tail I should say about halfway across the heaven, gradually disappearing, but not entirely gone, I should think, for 5 minutes. The star appeared about the size of a cocoanut, and caused a grand illumination, so much like summer lightning that a friend whom I met afterwards walking in the opposite direction, and who had not seen the star, asked me if I saw the lightning, when I pointed out what it was, and showed him the tail A similar one appeared in about 10 minutes, but not quite so bright, taking *its course from a little nearer north*, and stopping a little nearer south Both of these stars were larger and brighter than any I ever saw before, and they increased twofold in size and brightness as they went" A sketch is annexed showing the courses of the meteors Nos 1 and 2, the first from about N E by N to S W by S, and the second on a course from about N N E to S S W, both tracks extending between points at no very great altitude and at nearly equal apparent elevations above the horizon in those directions It appears probable that both of these large meteors were Perseids of considerable brightness, of which the first, however (at about 11ʰ 23ᵐ, as observed elsewhere), left the most conspicuous and long-enduring light-streak on its course

Meteor of August 15th, 1876, about 9ʰ 30ᵐ P M, Bath (Mr W Bush) —"On the above evening I took a seat in my garden at about 9ʰ 45ᵐ P M at the back of the house, which faces the south-west I had scarcely been seated more than a minute, when I beheld an exceedingly brilliant meteor of a bluish colour, having a very long white train It was the second largest meteor I have ever seen It was at first perceptible to me on the eastern extremity of Ursa Major, but a little nearer the horizon, I should say at an apparent altitude of about 45° It travelled somewhat obliquely downwards from north-east to south-west, and it finally disappeared behind some houses In its transit, which occupied several seconds, it passed behind a cloud, and emerging from thence was again equally brilliant" [The duration given is 20 or 30 seconds, but this cannot be regarded as more than a very rough estimation of the real duration of the meteor's flight The point of first appearance described is between Arcturus and the tail-stars of Ursa Major, which were on its left, or "eastern extremity" (practically), *in the observer's* situation facing the south-west]

The account of this meteor's appearance by Lieut H de H Haigh at Penn Ilthon, Newtown, in Wales (other particulars of his description being given in the above list), was as follows —"At first it appeared larger, but not much more brilliant, than an ordinary shooting-star but it rapidly changed colour from light yellow to red, and finally to a dazzling white resembling the magnesium light, but far more intense, at the same time giving off volumes of smoke, which trailed behind it like the tail of a comet Its light about the middle of its course was so brilliant that one could have read by it"

At Pontardawe, Swansea, it is described as the largest meteor ever seen in the district, falling in the north, and illuminating the country for miles around

At St Clear's, near Caermarthen, a splendid meteor, with a light like that of daylight, moved rapidly "eastward," followed by a train of most brilliant hues—green, orange, crimson, and violet It lasted for about eight seconds Mr J P Norris, at Bristol, wrote —"A splendid meteor has this moment fallen due west of this house It first appeared in the neighbourhood of Arcturus, then seemed to burst and trail light of rainbow colours, and was visible nearly to the horizon slanting *towards the north.* Its distance cannot have been great, for we saw it for two thirds of its course against a dark cloud It may therefore have fallen in the neighbourhood of Clevedon"

The direction of the meteor's motion in these accounts, its long duration, and the absence of a persistent light-streak on its course, proves it not to have been a Perseid, and the radiant was found by Mr. Denning, from other descriptions of its apparent course, to have been in the constellation Aquila. A similar optical illusion to that described by Mr. Norris, of the fireball appearing to be projected on a background of dark cloud during a part of its course, was noticed by an observer of the large fireball of September 14th, 1875, at Faringdon, Berks, Mr. W. Dundas, who writes that "the sky above was cloudless; but shortly before I lost sight of it some heavy clouds low in the sky (and before and after invisible) were brightly displayed as it passed them. To me it seemed at the time as if the meteor passed *between* me and them, and that the light on them was *reflected*, not *transmitted*. Of course, if the meteor was seen also at Bath it could not be so; but it suffered no visible diminution of brilliancy while passing these clouds" *.

An observer of the same meteor (August 15, 0.30 P.M.), at Cirencester, describes it as very magnificent, "passing slowly across the north-western heavens, about midway between Arcturus and the horizon. The colour was a vivid pale green, it left a greenish wake behind it, and burst with brilliant scintillations of whiter light."

II. LARGE METEORS.

1876, June 15, about 8^h 5^m or 8^h 15^m P.M. local time, Suez, and several stations on the Grand Canal.—In the 'Comptes Rendus,' vol. lxxxiii p. 28, a number of accounts from the station-masters at many places on the Suez Canal, from Suez to Rouville Simsah and Raz-el-beh, are reported by M. Lesseps of a very large detonating meteor which appeared at the above time. At the two latter places no sound of a detonation is described; but the meteor was extremely bright, bursting at last like a rocket, and moving in the south-east from west to east. This was also the direction of its motion at the midway station El-Ferdan, where its light was dazzling, its duration was three seconds, and a detonation followed it like distant thunder. The detonation was most violent at the "*déversoir*," where the meteor like a mass of white light moved from south to north, apparently approaching, and left in the zenith after its disappearance a comet-like cloud of light visible for several seconds (a perfectly similar appearance of the meteor was observed at Rameses). Almost immediately after its disappearance, a noise like that of thunder and detonations, which were for an instant terrifying, were heard. At the station of Kabret the meteor, intensely bright and lasting three seconds, was seen to burst like a rocket, and was immediately followed by a thunder-like report. At one of the southernmost stations the meteor seemed to fall in the neighbourhood, descending like a fiery dart, which burst at last, and sounds like distant cannons followed two minutes after its disappearance. At Suez the meteor illuminated the horizon brilliantly for a few seconds.

1876, July 8, about 8^h 55^m P.M. (local time), Indiana, U.S.—The following letter from Prof. D. Kirkwood appeared in the 'New York Tribune' of July 19, 1876, describing the appearance of a very brilliant fireball in the State of Indiana, U.S., on the above date, leaving a streak of light of unusual duration on its track:—

"SIR,—A meteor of extraordinary brilliancy was visible in all parts of

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* 'Astronomical Register' for April 1876, Appendix, p. 11

Indiana on Saturday evening, July 8, about five minutes before 9 o'clock. Observations of the phenomenon have been reported from Paoli, Bloomington, Indianopolis, Elkhart, and various other points—the distance apart of the first and last-named localities being over 270 miles. Mr. J. W. Hollingsworth, of Paoli, says, 'Spectators agree in giving it a path from N.E. to N.W., with an altitude of at first 20°, and disappearing below the horizon. One careful observer states that the streak of light following remained visible more than 40 minutes of time, and all agree in ascribing a diameter of one fourth to one third of a degree' At Indianopolis, according to the 'Daily Journal' of July 10, the meteor appeared 'in the constellation Cassiopeia at a point about 25° above the horizon, whence it proceeded in a right line to the north-west, and passed over an arc of about 30°, and vanished in space 10° above the horizon'

"According to the observations at Paoli and Indianopolis, the meteor became visible at an elevation of 130 miles above the earth's surface. It is to be regretted that sufficient data have not been furnished for determining its height at disappearance, the length of its visible track, and the eccentricity of its orbit."

III Periodic Star-Showers, 1875–76.

With the exception of the annual reappearances of the Perseids, there have been no marked occurrences of periodic star-showers during the past year. The few particulars relating to them which have been received will be described below; and the following details refer chiefly to the display of Perseids in 1875 observed on the continent, accounts of which in England, as described in the last Report, were obtained at a few stations only, owing to the stormy weather that prevailed on the principal periodic nights.

Star-Shower of August 9th–11th, 1875: *Observations by the French Scientific Association* ('Comptes Rendus,' vol lxxxi p. 439, September 6th, 1875).—Report on the shower in Switzerland and elsewhere, by Dr. C. Wolf, of Zürich. At Rochefort, Messrs. Simon and Courbebaisse counted, on the average of the whole time of their combined watch during the night of the 10th of August, 133 meteors per hour. At Avignon 858 meteors were mapped in the same night between the hours of 8.35 P.M. and 3h 40m A.M. by M. Giraud, assisted by several observers. At Lisbon, M. Capello noted at the Observatory of 'l'Infant Don Louis' what appeared to be a maximum reappearance of the shower, 1227 meteors being counted during the watch on the night of August 10th. Details of the shower and of the radiant-points distinguished in it were also received from M. Tisserand at Toulouse and from the Observatory at Marseilles.

Prof. Tacchini obtained at Palermo a number of distinct centres of radiation of the shower, of which the following is a list; and he remarks that all these definite centres, when projected on a map, are included, as he has already formerly observed, in a narrow elongated area.

	α =	δ =		α =	δ =		α =	δ =		α =	δ =
1875 Aug. 9th.	42°	+54°·5	Aug. 10th	43°·2	+54°·0	Aug 11th	44°·0	+53°·0	Aug. 12th	41°·5	+53°·3
	44·2	+50·5		41·0	+55·7		39·0	+56·3			
	44	+51·2		41·7	+54·5		41·7	+53·5			
				42·7	+51·3		44·5	+51·0			
				45·1	+52·0						

Average of all the above subradiant positions 42° 72, +53°·21.

At Dijon radiant-positions were also observed by Abbé Lamey, who noted the mean place of the principal radiant for all the nights at R.A. 37°, N. Decl. 45° (A), and recorded also the following general centres of showers which appeared to accompany the display:—at R.A. 320°·4, S. Decl. 1°·8 (B), and R.A. 331°, Decl. 0°.

At Bordeaux, M. Lespiault noticed the existence of several secondary radiant-points in or near the constellation Cassiopeia.

Notes of an abundant shower were also received from Rouen, Sainte Honorine du Fay, and from Courtenay, where M. Corun observed a remarkable light-cloud, or band of light, stretching with blunted terminations to a full length of 120°, and moving eastward, which he conjectures may have had some connexion with the display.

In addition to these observations collected and published in France under M. Le Verrier's superintendence, M. Ernest Quetelet communicated to the Belgian Academy of Sciences[*] an account of the August meteor observations made at the Royal Observatory at Brussels, and the following numbers of meteors were observed:—

	August 9th,	August 10th,		August 11th,
	10^h–11^h (much cirrus)	$9^h\ 55^m$–$10^h\ 55^m$, (some clouds)	$11^h\ 45^m$–$12^h\ 45^m$ (quite clear)	$9^h\ 50^m$ $10^h\ 50^m$ (clear)
No of meteors seen.	16 (3 observers)	31	59 (3 observers)	34 (2 observers)
Do. in order of brightness (descending from 1st to 6th magnitude).	3, 5, 7, 1, 0, 0.	13, 17, 34, 15, 8, 0.		2, 6, 10, 8, 7, 1.

Totals 18, 28, 51, 24, 15, 1

The largest meteor of the shower, at $11^h\ 15^m$ (Brussels time), on the 10th, exceeded Jupiter in brightness, and left a persistent streak visible for 20 seconds, which disappeared without presenting any indications of rapid currents in the upper atmosphere. Although a pretty bright display, this annual return of the August meteors was yet not so remarkable as to distinguish it as an exceptionally great reappearance of the shower.

At Cheadle, in England[†], a very similar view of the shower, confirming its marked but not very extraordinary intensity, was obtained by Mr. G. T. Ryves, whose observations of the Perseids in 1871, communicated to the Committee by Mr Symons, as follows, must have enabled him to make a fair comparison between the abundance of the meteors seen on this and on that earlier occasion:—"Took up a station at the top of the Wrekin with a party of friends for the purpose of observing the periodic display of meteors, Aug. 10th, 1871. Counted about 70 between $9^h\ 30^m$ and $11^h\ 30^m$ P.M., nearly all in the neighbourhood of the constellations of Perseus and Cepheus; none very remarkable. A larger number seen on our way home from $11^h\ 30^m$ P.M. to $2^h\ 15^m$ A.M., and of larger size, but not counted. One very brilliant one [see the fireball-list in this Report], about $0^h\ 38^m$ A.M., lighting up the country."

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[*] Bulletins de l'Acad. R. des Sciences de Belgique, 2ᵉ série, tome 39, 1875.

[†] 'Astronomical Register,' 1875, p 222. *Erratum.*—The position of the radiant-point of the Perseids in 1874 assigned by Mr. W. F. Denning at Bristol, in the 'Astronomical Register' of Sept 1874, "bewteen B, C Camelopardi and χ Persei, at R.A. $2^h\ 55^m$, D. 58° 30′ N.," was at R.A. 44°, N. Decl 58°·5; not, as misprinted in these Reports (for 1875, p. 213), at R.A. 39°, N. Décl. 58°·5.

October, November, and December Star-Showers, 1875.—Of the annual meteor showers in October and December no observations have been received. The state of the sky was unfavourable for continued observations on the periodic dates, and in the intervals of cloudless hours devoted at some stations to a watch the preparations for recording the Orionids and Geminids in 1875 were unsuccessful, these showers being apparently absent on the expected dates. At Stonyhurst Observatory a meteor-watch was kept on the mornings of November 12th and 15th, and also at the Royal Observatory, Greenwich, on the latter morning, with favourable conditions of the sky, but in bright moonlight*. In 2½ or 3 hours before daybreak on the first morning eight meteors were mapped at Stonyhurst College, two or three of which were Leonids, three Taurids, and the rest apparently sporadic. Twenty four meteors at Stonyhurst and twenty six meteors at Greenwich were mapped in 3½ or 4 hours of generally clear sky on the morning of the 15th, of which ten or twelve meteors noted at each place were Leonids, and the rest were either Taurids or were directed from less certainly determined radiant-points. On the intervening mornings of the 13th and 14th the sky was either wholly or almost entirely overcast.

The Geminids of December 11–13, 1875, were watched for in England without success on account of cloudy skies, and equally unfavourable conditions prevented any satisfactory observations of the meteors of the 1st–2nd of January 1876, from being made. But the night of January 1st proving clear at Sunderland, Mr. Backhouse saw two meteors, unconformable, on that evening, in a few minutes' watch, and towards five o'clock on the morning of the 2nd of January two others in 15 minutes, which were conformable to the radiant-point of the annual shower. On the following morning also, at about 2^h A.M., Mr. Backhouse noted one meteor only in a watch of 23 minutes, when the sky, which had been overcast before, cleared partially, and it was conformable to the radiant-point of the shower.

The following notice of some shooting-stars seen by the expedition under Captain Parry in the Arctic seas occurs in the narrative of his third voyage (p. 64), relating the events of the winter at Port Bowen in the year 1824, and it appears to indicate an appearance of the Geminids with considerable brightness in December of that year, but the description includes meteors from other radiants as well as a particularly bright one directed exactly from the radiant in Gemini of the annual shower. The changes of the weather which accompanied those appearances being regarded by Captain Parry as in some intimate manner connected with the apparition of the meteors, are described in full detail; but except to observe that the meteors seen appear to have been as exceptionally remarkable as the sudden changes of the weather with which they were presumed to be associated, the notable features of the wind and weather which are stated in the original account to have accompanied them need not here be reproduced at length, but only the passages of the narrative may be transcribed in which the apparent paths and appearances of the meteors seen were recorded with careful accuracy and completeness. The particulars of a few meteors thus successfully preserved will doubtless be held by navigators and explorers as offering them a useful example for repeating wherever practicable, and making known in future to the best of their information, such highly valuable observations. "The meteors called falling stars were much more frequent during this winter than we ever before saw them, and particularly during the month of December [1824]. On the 8th, at $7\frac{1}{4}^h$ P.M., a large and pretty brilliant meteor of this kind fell in the S.S.W. On the following day, between 4^h and 5^h P.M., another, very brilliant, was observed in the N., falling from an altitude of about 35° till lost behind the land. On the 12th no less than 5 meteors of this kind were observed in a quarter of an hour, . . . the account furnished me by Mr. Ross, who with Mr. Bell observed the phenomena [. . . . . was] as follows:—At 11^h 15^m my attention was directed by Mr. Bell to some meteors which he had observed, and in less than a quarter of an hour five were seen. The two first, noticed only by Mr. Bell, fell in quick succession, probably not more than two minutes apart, the third appeared about eight minutes after these, and exceeded in brilliancy any of the surrounding stars. It took a direction from near β Tauri, and passing slowly towards the Pleiades left behind it sparks like the tail of a rocket, these being visible for a few seconds after the meteor appeared to burst, which it did close to the Pleiades [the direction of this meteor is exactly from the radiant-point τ Geminorum, close behind it, of the Geminids of December 12th]. The fourth meteor made its appearance very near the same place as the last, and about 5^m after it. Taking the course of those seen by Mr. Bell, it passed to the eastward, and disappeared halfway between β Tauri and Gemini. The fifth of these meteors was seen to the eastward, passing through a space of about 5° from north to south, parallel to the horizon, and moving along the upper part of the cloud haze which still extended to the altitude of 5° or 6°. It was more dim than the rest, and of a red colour like Aldebaran. The third of these meteors was the only one that left a tail behind it as above described. There was a faint appearance of aurora to the westward, near the horizon." [With the exception of the third of these five meteors, the radiants from which they were directed are undetermined, and appear to have had no connexion with that of the annual meteor-shower in Gemini.]

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* 'Monthly Notices of the Astronomical Society,' vol. xxxvi. pp. 83 and 272 (December 1875 and March 1876).

The April Meteors in 1876.—No intimations of the appearance of the Lyraids on the nights of April 18th–20th, 1876, have reached the Committee, probably owing to the very unfavourable weather for observation which prevailed. This year being a leap-year, the occurrence of the shower might be expected to be a day earlier than on ordinary years (April 19th–20th); and the following letter in 'Nature' (vol. xiv. p. 26) from Professor Kirkwood, of Bloomington, Ind., probably describes a considerable apparition of these meteors in the United States on the expected meteoric date.

"Between 10 and 12 o'clock on the night of April 18th, Mr. W. L. Taylor, a member of the Junior Class in the State University, with several other gentlemen, observed an unusual number of shooting-stars. These gentlemen were returning in an open waggon from Elletsville, eight miles north of Bloomington. No count was kept of the number of meteors observed, but the appearance was so frequent as to attract the attention of all the company. Mr. Taylor thinks the number noticed cannot have been less than twelve or fifteen. From the descriptions given of the meteor-tracks, I find that they were nearly conformable to the radiant of the Lyraids. The meteors were remarkably brilliant, apparently equal to stars of the first or second magnitude. At my request, Mr. Benjamin Vail, a student of the University, made observations on the nights of the 19th and 20th of April. Both nights were so cloudy, however, that a continuous watch would have been useless. About 11 o'clock on the night of the 19th three meteors were seen in the north-west, where the sky at the time was partially clear."

The August Meteors in 1876.—A large list of observations of the Perseids, in 1876, has been communicated to the Committee by observers at Birmingham, Bristol, Buntingford (Herts), Hawkhurst (Kent), Sunderland, and York; and the past year's list of meteor observations at the Radcliffe Observatory, Oxford, contains very numerous observations on the meteors of the shower. The state of the sky was generally very favourable for observations (although the moon had passed its first quarter during the second week in August), and the number of observations is rather ascribable to this cause than to any great intensity of the shower which was observed. The maximum hourly frequency of the meteors noted by one observer at any time during the watch scarcely exceeded twenty-five or thirty meteors per hour, of which five or six were unconformable and the rest Perseids, and the latter were not conspicuous in brightness or in leaving very persistent streaks. A few large Perseids were recorded, details of the brightest of which (on the 11th at $11^h\ 22^m$, and on the 13th at $9^h\ 27^m$) are included in the descriptions of large meteors given in the foregoing list. The maximum frequency of the meteors took place during the night of the 10th to 11th of August, when one observer might count from 25 to 30 Perseids in an hour; but the number visible on the nights of the 9th and 11th were much less than this, and not more than 15 or 20 Perseids could be noted in the same time. Their radiation was in general accurate, and the centre of divergence of the recorded paths was not far from the usual position of the radiant-point of the shower near η Persei. The number of unconformable meteors visible during the period of the annual watch was about 6 or 8 per hour, and more than 60 of their paths were mapped. The radiant-points which they indicate are very numerous, their tracks belonging, with very little apparent ascendancy of any particular shower, to almost all those known to be in activity during the time of continuance of the August shower. Several accordances of meteors simultaneously observed at distant places, besides those of large meteors above mentioned, are contained in the observations; and of these and of other points of special interest in the several descriptions the Committee trust to communicate the details, and an account of the results of a complete discussion which they are at present undergoing, in another year's Report.

The annexed extract from the 'English Mechanic' of September 8, 1876, contains, besides some observations on the shower, a notice of a large Perseid of which some other exact observations are described (at p. 184) in the general fireball list of this Report:—

"*August Meteors.*—The following note of the August meteors as seen from this place may interest some of your readers. On the night of the 10th, between $9^h\ 15^m$ and $1^h\ 15^m$, 134 were observed. Of those seen before midnight the greater portion appeared to have a radiant-point in Cassiopeia, but those seen afterwards came from the cluster χ Persei. The numbers observed during this month are as follows:—

Date, 1876, August	9th,	10th,	11th,	12th,	13th,	27th,
Meteors observed	21	134	25	8	13	12

One of the meteors seen on the 13th deserves special mention. It appeared at about $9^h\ 27^m$, as nearly as I could judge, in semidarkness, moving in a line from χ Persei, and passing with a rapid motion across a small star distant about 30′ (minutes of arc) vertically over δ Ursæ Majoris. It was as bright as Venus, and it left a tail for 4 or 5 seconds.—J. Parnell, Folkestone."

Special Catalogues and General Comparative Lists of Meteor-Showers.

As the scattered lists of meteor radiant-points, or general centres of divergence of shooting-stars, on ordinary nights of the year are at present, from the dispersed materials and limited accessibility of such catalogues, most unserviceable for the use of observers, the attempt which has during the past year been made by Mr. Greg to present a carefully condensed and revised collection of all such observations in a single comprehensive list will be recognised by assiduous recorders of shooting-stars as affording them an invaluable fund of useful information on the previously ascertained positions of all the best known and best determined radiant-points of such probably distinct showers or meteor-systems as they may meet with in their observations. With a view to grouping new observations of the places and durations of shower-apices under the best-established average dates and directions of the hitherto known centres of divergence of ordinary shooting-stars, Mr. Greg compiled last year a valuable condensed list of meteor-showers from all the published catalogues and observations accessible to him, including all the older and all the most recently recorded showers of the northern or southern hemispheres visible in the latitude of Greenwich. A single chart illustrating the list was at the same time drawn by Mr. Greg, and it was the intention of the Committee to have printed and issued this catalogue and map, together with an introduction containing directions for their use, in the form of a separate pamphlet during the past year to assist observers; but the additional matter sought to be included with it in the pamphlet being yet unfinished, and the necessity felt by observers for a full and correct list of the known *average* centres of radiation of ordinary shooting-stars being one of the most urgent and important of the requirements which it has been the object of the Committee during the past year to supply, the course which it has appeared to them most desirable to adopt (the first stage of the projected compilation having thus far been completed) is to present Mr. Greg's Catalogue and Map (which here follow) in this Report, as a useful companion to observers for reference and guidance in recording appearances of meteor-showers. The reference-numbers of the list coincide with those of Mr. Greg's earlier list (contained in the volume for 1874 of these Reports), with some rearrangements and with considerable additions (from the last No., 187, of the earlier list *) to embrace new showers. By consulting the earlier list, references more or less complete will be found to all the original observations of these meteor-showers; and with the assistance of the key-map a ready and convenient, and for the most part perfect, means is thus afforded of determining the degree of importance or the possible distinctness of a newly observed meteor radiant-point from any previously known observations of meteor-showers resembling it which may already have been elsewhere recorded.

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* In the new entries some numbers temporarily assigned last year (these Reports for 1875, p. 228) to new showers there for the first time pointed out are not uniformly adhered to in the following list, which is condensed and extended throughout, directly from the last similar complete comparative list of the year 1874.

A general Comparative Table of Radiant positions and Duration of Meteor-showers visible in the Northern Hemisphere, by R P Greg, F.R A S &c , 1875, accompanied by a Map (Plate IV)

Collated from the Catalogues of Prof Heis, Signors Schiaparelli and Zezioli, Dr J Schmidt, Capt G L Tupman British Association Reports 1850–1874, the Radcliffe and Royal Observatory (Greenwich) Catalogues of Observations of Shooting stars, Drs Neumayer and Heis s Results of Meteor Observations in the Southern Hemisphere and from other sources

Progressive No in the Brit Assoc Cat. (vol of the Reports for 1874) continued 1875	Epoch or Duration of Meteor showers	Average Radiant position.		No of Radiants or Sub radiants averaged.	Standard of supposed relative importance of Meteor shower	Observations Authorities, &c Radiant area supposed to be about 10° in diameter [GH =Greg and Herschel, 1850–67 GH*=Brit Assoc 1867–74 GZ =Greg and Zezioli 1867–69 H = Heis N = Neumayer S = Schmidt SZ.= Schiaparelli and Zezioli T =Tupman]
		R.A.	N D			
I.	II	III	IV	V	VI	VII
1	December 20 to February 26	116°	+87°	6	*b* 1	GH S. H 4 *Polarids* No I
2. (25a.)	December 13 to February 15	131	+48	11	*b* 1	GH SZ. 5 H (No 25*a*=131° +52° Feb. 6 15) Tupman Denning 2 Corder
3	January	104	+18	2	*c* 2	SZ
4	December 27 to January 29	201	+54	3	*b* 2	GZ SZ. 8 Noticed since 1867
(35.)	February 14–15	209	+52	2	*c* 3	SZ Probably No 4 continued
5	December 23 to February 10	168	+ 8	4	*c* 2	T Maximum 1870? (=No 184?)
6.	December 26? to January 10?	232	+49	7	*a* 2	GH T H 1 Backhouse and others maximum Jan 2–3 A.M 1863–66 and generally observed since *Quadrantids*. Distinct from No 17
7	December 1 to January 31	22	+56	6	*b* 2	GH SZ H 2.
8	January 5 to February 13	204	− 2	4	*c* 2	T 2 Maximum 1870?
9	December and January	146	+33	3	*c* 1	T N (145° −25° and 146° −40°)
11	December 22 to February 6?	180	+35	8	*b* 1	GH T 2. H SZ. 5 (Radiant-area large)
12.	January 19 to February 21	208	+27	5	*b* 2	SZ. 4. T (Seen since 1867) Denning 210° +36°
13.	January 27 to March 20?	136	+69	3	*c* 1	GH SZ Denning
14.	December 20? to February 6	67	+22	3	*c* 1	GH SZ. Denza. *Taurids*, II
14a.	February 27 to March 6	60	+37	1	*d*	GH* (?=No. 14)
15.	January 1 to March 16	141	− 2	3	*c* 1	GH. T (Clark, Jan. 1–3, 1871 127° ±0°)
16.	January 9–19 ...	72	+ 4	2	*c* 3	G (reduced from Denza s observations 1868)
17	January 1 to February 6	225	+54	[illegible]	*c* 1	H. 2. G from Denza s observations. SZ Denning
18.	January 18 to February 13	230	+30	11	*b* 2	GZ. SZ. 7 T 2

19	February 1–14	61	+56	1	*d*	H Probably same as No 38.
19*a*.	January 15 to March 15	65	+61	1	*d*	GH*
20.	February 13 to March 3	200	−16	2	*c* 3	T (? commencement of No 44)
21. (46.)	February 6 to April 25	180	+56	7	*b* 1	SZ. 2. H. 3 GH Corder at 170°, +58°
22.	February 10 to March 7	280	−17	2	*c* 3	T (A.M.) (270° −22° to 290° −12°)
23.	February 3–17	219	−18	2	*c* 2	T 2 [=Comet III. 1759 Jan 19 at 210° −15°?]
24.	February 9 to March 27	75	+44	4	*c* 1	SZ. H. GZ (GH* at 60° +37° Feb. 27 to Mar 6)
25.	March 1 15	120	+54	1	*c* 2	H
26.	February 3 to March 31	158	+29	5	*b* 1	GH SZ. 8 GH* Corder
27	February 13	260	± 0	1	*c* 2	T [?=Comet IV of 1858, Feb. 13, at 272° +12°]
28	January 8 to March 31	175	+14	7	*b* 1	GH. N H 3 T 2 *Virginids*, No. I
28*a*.	March	181	+ 6	1	*c* 3	N Same as 28
29 (39)	February 11 to March 3	205	+17	2	*c* 2	GH T [=Comet 1797 Feb. 18, at 210° +10°?] Denning and Corder at 209° +18°
30. (40)	February 17 to March 3	249	+45	3	*c* 2	SZ. 2 T Meteors small.
31	February 13	133	+26	1	*c* 3	SZ Meteors small
32.	February 14	105	+62	1	*c* 3	SZ. Meteors small.
33.	February 14–28	263	+68	1	*c* 3	H SZ 3 No doubt identical showers (Also SZ
34.		245	+76	2	*c* 2	N 242° +63° end of January) ?=179*a*
188.	February 11 27	105	− 5	1	*c* 3	Denza, 1868
36.	March 1	142	−25	1	*d*	T (doubtful ?=No 15).
36*a*.	March and April	125	−40	4	*c* 1	T N 2
37	February 28 to March 12	83	+ 6	1	*c* 3	S Denning
38 (19)	March 1–15	50	+48	3	*c* 2	GH H and confirmed by Italian observations.
39	March 2–3	209	+18	1	*c* 3	T
41	March 2–7	248	+12	3	*c* 2	T 3. Maximum 1869–70? (?=41*a*).
41*a*	March 3–25	247	− 2	2	*c* 3	GZ T [=Comet V 1864 March 1 at 251° −12°?]
41*b*	March 2–7	235	−15	2	*c* 3	T ?=41*a*.
42.	March 2–19	192	+ 2	3	*c* 2	T 2. GH *Virginids* No II
(62)	April to June 3	199	+ 9	3	*c* 1	GH H GH* *Virginids* No III (?=No 42)
43	March 9–27	105	+39	2	*c* 3	GZ In 1863 (98° +46° and 112° +32°)
190	March	174	−30	1	*c* 3	N [=Comets 1264 1556 Mar 19–25 180° −27°?]
44	March 1 to April 30	197	−32	4	*b* 2	N 2 T 2. Well observed in Australia.
45	March 16 to April 25	147	+47	6	*c* 1	GZ SZ. 2. H GH* Clark (=No 56?)
189	March 3–17	36	+67	1	*c* 3	GH (=No 5 of B A Cat of 1867)
189*a*.	March 1 15	15	+80	1	*d*	Heis
47	March 11 to May 31?	263	+50	9	*b* 1	GH SZ 6 Greg GH* *Draconids* No I Shower probably waning since 1870
48.	March 12 to April 30	223	+42	1	*c* 2	GH Probably connected with No 71
49	March 15 to April 21	307	+40	2	*c* 2	GZ. Denning (21st April, 1872 at 310° +44°)

Table of Radiant-positions and Duration of Meteor-showers (*continued*).

I.	II.	III.	IV.	V	VI.	VII.
50.	March 2 to April 25...	265	+25	6	c 1	GH. SZ. T 2. Greg, April 20, 1872, at 267°, +25°. Meteors white or paler and more trained or phosphorescent than *Lyraids*. A. S. Herschel at 273°, +25¼° 13–14 April, 1864. *Cerberids*,?=Comet I of 1861.
51.	April 5? to May 10?	272	+35	8	a 2	GH. H GH*. Serpieri, Denning Lucas, Greg, Weiss. Maximum 19–20 April, A.M. Meteors yellow, white, and orange, slightly trained. *Lyraids*. =Comet I 1861 (? if the agreement with the comet is perfectly exact). Denning, Italian, 265°, +38°.
52.	March 25 to April 30 ..	290	−10	2	c 3	GZ. GH* See No 22 and No 205
53.	March 20 to May 29...	225	− 8	2	c 2	GH. S (? different from No. 53*a*). 26 meteors.
53*a*.	April 1–30?	226	+10	3	c 3	T, Denning, GH* (230°, +5° and 221°, +15°)
54.	March 25 to April 30	190	+24	6	b 2	GZ. SZ. 2. H. 2. N
55.	April 1 to May 25	204	+56	7	b 1	GH. SZ. 4. Serpieri, GH* Dn. at 210°, +66°
56.	April 10–30	162	+48	3	c 2	H. SZ. 2 (See No 45?)
57.	April 1–30 . . .	237	+63	2	c 3	SZ. S. (240°, +55° and 233°, +71°)
58.	April 27	256	− 2	1	c 3	T.
205.	April 27–30	279	−28	3	c 3	T 2. Denning at 277° −25°.
59.	March 18 to April 20 .. .	154	+17	3	c 2	GZ., Backhouse from 20 meteors Dn 142°, +15°.
59*a*.	April 29 to May 25?	160	+12	3	c 2	GH S. (=Radiant Y of G & H)
60.	April 1 to May 4	228	+81	8	b 2	SZ. H. 3 Clark. GH. at 75°, +87° S Denning.
65.	April 27 to June 30	289	+81	3	c 1	GH. H. 2, probably No 60 continued. *Polarids*, III.
65*a*.	June 1–30 . . .	158	+83	3	c 3	Hess. =No 60 or 65 (Included in average of No. 65.)
61.	April 29 to May 2	326	− 2½	3	c 3	T (? maximum 1870 and 1871. Meteors swift and bright-trained, a fine A.M. shower, well defined).
63.	April 29 to June 12	123	+40	1	c 3	GH. (8 meteors mapped).
64.	April 20 and May 25	281	+57	2	d	SZ. Denning (?=No 47).
66.	May 2...	291½	+ 8½	2	c 3	T Well-marked shower
67.	April 12 to June 30	235	+23	8	b 2	GH. SZ 3. H. 2. GH* (? diminishing since 1872).
68.	May 1 to June 30..	329	+48½	2	c 3	H. 2. ($B_{1,2}$ at 325°, +55°, and 333°, +42°, connexion doubtful, or B_3 and its concentred showers.) (See No. 77) Comet I. 1781, June 14, 338°, +57°.
69. 72.	May 6 to June 30.................	280	+34	5	b 2	GH. SZ. 2. S GH* (? also SZ. at 263°, +38° for 18 May)

70.	May 23-24	301	+37	2	*c* 3	SZ. (?=No. 74).
71.	May 15 to June 2	235	+45	3	*c* 2	SZ. 3. (SZ. at 237°, +59°, May 26)
73.	May 2 to June 9	206	+39	3	*c* 3	SZ. Small meteors.
74.	May 8 to June 30.	310	+24	5	*b* 2	GH. H. SZ.? S. GH*. (? commencement of No. 101).
75.	June	253	−37	1	*c* 1	N Probably same as No. 75*a*, July.
75*a*.	July	245	−30	1	*c* 3	S.
76.	June 29	168	+55	1	*c* 3	GH. 7 meteors only mapped.
77.	June 11 to July 31	317	+62	8	*b* 2	GH H. 2. SZ. 5 (? =No 68 for May, Heis). Comet I. 1850, June 24, 312°, +60°
78.	June 28 to August 25?.	282	+60	12	*a* 2	GH. SZ. 7 T GH* H., Miss Herschel *Draconids*, No. II.
204.	June 24 to July 6	285	−13	4	*c* 3	T (Possibly connected with No 79)
79.	June 1 to July 25	299	− 7	6	*b* 1	S. 3. T 2. N. Radiant possibly elongated. *Aquilids*, No I.
79*a*. 107.	June 7 to August 12?	301¼	+ 8¼	9	*b* 1 *a* 2	GH. N T 2 S. 2 GH* Weiss, Denza. *Aquilids*, No II. Possibly all one shower with elongated radiants.
80. 85.	June, July, August	264	−11	6	*b* 2	S 4. N 2.
81.	July 5 to August 31	309	+48	15	*a* 2	GH. SZ. 10 T H. GH* Clark. *Cygnids*, No. I.
82.	July 1-6	237	± 0	1	*c* 3	T
83.	July 4 to August 4?	12	+64	2	*b* 2	GH GH* SZ. Denning, Tacchini. *Cassiopeids*, No. I.
86.	July 11 to August 20?	7	+50	6	*c* 2	SZ. 5 *Cassiopeids*, No II (Pseudo?)
84.	July 5-12?	214	+55	5	*c* 1	GH. SZ. GH* GZ. Serpieri 1868-9 (Max.)?
87.	July 1-25	270	+ 7	3	*c* 3	H. S. 2. (262°, +12° and 279°, +7°)
88.	July 4 to September?	249	+19	2	*c* 3	GH S. Probably same as Nos. 90, 110
90. 110.	June to August 31	257	+30	5	*c* 2	S 3. SZ Herschel. (Centre at 257°, +36°)
89.	July 4-11	210	+20	2	*c* 3	GH. GZ.
91	July	284	−40	1	*c* 1	N (Possibly same as No. 91*a*.)
91*a*.	July, August, September	285	−24	5	*c* 1	S
92.	July 18-25	310	−30	1	*c* 3	S
198.	July 21-28	323	− 8	3	*c* 3	T S (Possibly commencement of No 198, Sept)
93.	July 1 to September 10	302	+87	8	*b* 1	GH H 4. T 2. GH* *Polarids*. IV
94.	July 20 to September 20	339	−34	5	*a* 2	N 2 S 2. A. S. Herschel (Max. 27 July-10 August)
95.	July 18 to August 2	340	+41	8	*b* 2	SZ. 5. T. Hind. GH* *Honorids* Possibly same as 112.
96.	July 1 to August 15	338	+26	8	*c* 1	GH. S 2. SZ. 4. Greg. *Pegasids*, I. Radiant possibly multiple or elongated.
97.	June 28 to September 15	338	+17	10	*b* 1	GH GH* S. 3. H T 2 Greg. Herschel. *Pegasids*, II Probably distinct from No 96
99	July 28 to September 6	170	+54	3	*c* 1	GH*. SZ. S. (Well marked since 1870.)
108. (121*a*.) (132.)	July 30 to September 23	26	+35	5	*b* 2	SZ. 2. T. SZ. GH*

Table of Radiant-positions and Duration of Meteor-showers (*continued*)

I.	II	III	IV	V	VI	VII.
121	August to September 10	22	+19	2	*c* 3	S 2 (Wants further confirmation)
101	July 4 to August 31 ?	315	+30	4	*c* 1	GH S ? T *Cygnids* II See Nos. 74 and 119
101*a*	September	311	+35	1	*c* 3	S (? Continuation of No 101)
102	July 9 to August 20	348	+62	6	*c* 1	GZ S GH S SZ 3 Well observed since 1868
103.	July 21 to September 3 ?	7	+33	11	*b* 1	GH T 4 SZ GH* S 2 Dz Dn *Andromedes* I.
104	July 29 to August 31	50	−19	2	*c* 2	T S
104*a*.	September 3–7	66	−22	1	*c* 3	S (? Continuation of No 104)
105	July August September	9	− 9	6	*c* 1	S
106	July to September 10	15	+ 1	5	*c* 1	S *Piscids*
108	July 23 to August 20	44	+56	35	*a* 1	GH H SZ T &c *Perseids.* Radiant rather diffuse perhaps elongated. Max 9–11 Aug 1st — Comet III 1862
109 (137)	July 5 to October 31	337	− 6	18	*a* 2	S 11 T 2 N GH* Weiss. *Aquarids*
111 (126.) (86.)	August 6 to October 10	3 9	+13	13	*b* 1	GH H 2 T 3 S 4 GH* Tacchini *Pegasids* III Position in map at 354 R A slightly incorrect.
112	August 6 to September 30	335	+52	8	*b* 2	GH H 2 T SZ ? Greg Weiss *Lacertid*
198	July 20 to September 30	328	−12	7	*b* 2	S 5 T 3 Perhaps connected with No 109
113	July 29 to September 25	281	+38	5	*b* 2	GH SZ 2 S GH*
114.	August 3 to September 15	67	+47		*c* 2	G T 2 (Radcliffe Observations 1870–1871)
115	August 5–12	50	+24	5	*c* 1	GH S GH* SZ Weiss 46° +73° Aug 11 1869
116	August 7 to September 20 ?	58	+57	9	*c* 1	H 3 GH* Forbes T 4 (Aug 10 1868) Probably distinct from No 108
116*a*.	August 8–11	25	+59	3	*c* 3	Parnisetti Lorenzoni
117	August 3 to October 31	53	+ 6	5	*c* 2	S 4 Clark N See No 138
117*a*.	September 13 to October 22	65	+ 3	5	*c* 1	T 4 S (N B Erroneously marked 174*a* in Map)
117*b*	September 3–30 ?	51	+14	1	*d*	S Probably = No 117
203	August 31	85	−15	1	*d*	S. (= No 126*a* of 1874 B.A Cat)
118	July 5 to August 31	318	+ 7	4	*c* 3	H S 3
119	August 23 to September 25 ?	303	+23	2	*c* 3	GH* T (Epoch requires confirmation) See No 101
200	August 20–25	110	+32	1	*d*	T (=119*a* of 1874 B A. Cat.)
120	August	258	−38	3	*c* 3	N S 2 (250° −35° and 266° −42°)
122.	August 6 to September 30	95	+62	5	*b* 2	GH* T Lucas Denning's 40 Italian meteors gave 101° +57° R.A. in Map incorrect.
124.	August 20–25	264	+64	1	*d*	T (Wants further confirmation.)
125	August and September	345	+65	3	*c* 2	GH* SZ. T S, at 354°, +52°
192.	September	50	+75	1	*c* 3	GH*
193.	September 5–20	319	+53	2	*c* 3	SZ Probably connected with Nos 151 112 or 81

127	*August 8–17 to September*	145	+67	2	*c* 3	S
128. 143.	September 1 to October 31	105	+86	5	*b* 2	GH. H. 4. (Gruber at 250° +87° Oct 22–28.)
129 (123.)	August 22? to October 20	46	+35	12	*b* 1	GH T 4. SZ 3 H. 3 GH* (*Muscids*) Gruber at 39° +30° Oct 19
130	September 1 to October 15	302	+62		*c* 2	H 3 S 2.
131.	September 7–15	60	+61	4	*c* 3	SZ 2 T 2
139	October 1 15	57	+61	1	*d*	H Possibly same as No 131
133	September 27 1864 ..	17	−10	1	*c* 1	Prof Herschel. (Well pronounced near *θ Ceti.*) ?=No 105
134	September to October 27	78	+11	3	*c* 3	S. 2. T (?=No 135)
135	August 29 to October 31	74	+27	11	*b* 2	GH* SZ. T 6 S 2. Tacchini (GH* at 68° +17°, Sept) Possibly continued at No [illegible]10
136 (201)	September 17 to November 25	84	+48	8	*b* 1	GH SZ 3 T S H A S. Herschel *Aurigids* I
138.	August 7 to October 31	40	− 6	8	*b* 2	N S 4 T 3. *Eridanids*
138*a*	October 7–14	43	+ 3	4	*c* 3	T 4 Probably = No 138.
140	September 25? to October 24	247	+68	3	*c* 2	SZ. 8 GH*
141	October 3–21	136	+46	2	*c* 2	GH T
142	September 25? to October 25	105	+27	5	*c* 1	GH* T SZ Denning Gruber Herrick, 1839 Max 23 Oct *Gemellids.*
144 (160)	October 15 to November 6	342	+56	4	*c* 2	H S 2 GH* (GH* = 325° +60°)
199	October 1 to November 13	352	+34		*c* 3	SZ. 2 S.
145	October 16–31	21	+41	2	*d*	H GH* Possibly a pseudo-radiant
146	October 18–29	287	+47	2	*c* 3	GH GH*
147	September 1 to October 1[illegible]	129	+26		*c* 3	GH* T SZ (Since 1869)
148	October 11 12, 1869	93	+21	2	*c* 3	T
152.	October 5–27	87	− 3	7	*c* 1	T 6 S Maximum Oct 13
152*a*.	October 12–13	77	−10	[illegible]	*d*	T Probably connected with No 152
149	October	145	+18	2	*c* 3	T S (? an early subradiant of the *Leonids* No 171)
150	October 13 to December 8	28	+ 8	5	*c* 2	T 2 S GH* Backhouse at *o* Piscium, Oct 30 1874
151 (161)	October 19 to November 13	312	+48	2	*c* 3	S (At 316° +44° Oct and 307° +53° Nov 1 13) Max October 23
153 (155)	October 8 to November 15	107	+ [illegible]	7	*c* 1	S. 2 T 5
154	October 19 to November 20	34	+23	4	*c* 2	T S GH* Denning Possibly = Nos 150 or 120
154*a*	October 17 24	21	+22	3	*c* 2	Gruber (Radiants I. VII, XIII.)
156	October 21 to November 30	60 (55 +16 to 65 +24) (58 +19 Gruber)	+19¼	11	*a* 2	GH GH* SZ. T 6 H Denning Wood, Herschel, Backhouse Denman (Greenwich 55° +25° Nov 13) Well marked shower Radiant perhaps double (Tupman) or elongated? *Taurids*, I.

Table of Radiant-positions and Duration of Meteor-showers (*continued*)

I.	II	III	IV	V	VI	VII
121	August to September 10	22	+19	2	*c* 3	S 2 (Wants further confirmation)
101	July 4 to August 31 ?	315	+30	4	*c* 1	GH S 2 T *Cygnids* II See Nos 74 and 119
101*a*	September	311	+35	1	*c* 3	S (? Continuation of No 101)
102.	July 9 to August 20	248	+62	6	*c* 1	GZ S GH S SZ 3 Well observed since 1868
103.	July 21 to September 3 ?	7	+33	11	*b* 1	GH T 4 SZ GH* S 2 Dz Dn *Andromedes*, I
104.	July 29 to August 31	50	−19	2	*c* 2	T 8
104*a*.	September 3–7	66	−22	1	*c* 3	S (? Continuation of No 104)
105	July August, September	9	− 9	6	*c* 1	S
106.	July to September 10	18	+ 1	5	*c* 1	S *Piscids*
108	July 23 to August 20	44	+56	35	*a* 1	GH H SZ T &c *Perseids* Radiant rather diffuse perhaps elongated. Max J 11 August — Comet III 1862
109 (137)	July 5 to October 31	337	− 6	18	*a* 2	S 11 T 2 N GH* Weiss *Aquarids*
111 (126.) (86.)	August 6 to October 10	359	+13	13	*b* 1	GH H 2 T 3 S 4 GH* Tacchini *Pegasids* III Position in map at 354 R.A. slightly incorrect.
112	August 6 to September 30	335	+ 2	8	*b* 2	GH H 2 T SZ 2 Greg Weiss *Lacertid.*
198	July 20 to September 30	328	−12	7	*b* 2	S 5 T 2 Perhaps connected with No 109
113	July 29 to September 25	281	+38	5	*b* 2	GH SZ. 2 S GH*
114.	August 3 to September 15	67	+47	5	*c* 2	G T 2 (Radcliffe Observations, 1870–1871)
115.	August 3–12	50	+24	5	*c* 1	GH S GH* SZ Weiss 46° +53° Aug 11 1869
116	August 7 to September 20 ?	38	+57	9	*c* 1	H 3. GH* Forbes T 4 (Aug 10 1868) Probably distinct from No 108
116*a*.	August 8–11	25	+59	3	*c* 3	Parnisetti Lorenzoni
117	August 3 to October 31	53	+ 6	5	*c* 2	S 4 Clark, N See No 138
117*a*.	September 13 to October 22	65	+ 3	5	*c* 1	T 4 S (N B. Erroneously marked 174*a* in Map)
117*b*	September 8–30 ?	51	+14	1	*d*	S Probably = No 117
203.	August 31	85	−15	1	*d*	S (= No 126*a* of 1874 B A Cat.)
118	July 5 to August 31	318	+ 7	4	*c* 3	H S 3
119	August 23 to September 25 ?	303	+23	2	*c* 3	GH* T (Epoch requires confirmation.) See No 101
200	August 20–25	110	+32	1	*d*	T (=119*a* of 1874 B A. Cat.)
120	August	258	−38	3	*c* 3	N S 2 (250° −35° and 266° −42°)
122	August 6 to September 30	95	+62	5	*b* 2	GH* T Lucas Denning's 40 Italian meteors gave 101° +57° R.A. in Map incorrect.
124	August 20–25	264	+64	1	*d*	T (Wants further confirmation)
125.	August and September	345	+65	3	*c* 2	GH* SZ. T 8, at 354°,+52°
192.	September	50	+75	1	*c* 3	GH*
193.	September 5–20	319	+53	2	*c* 3	SZ. Probably connected with Nos 151 112, or 81

1876	127	*August 8–17 to September*	145	+67	2	c 3	S
	128. 143.	September 1 to October 31	105	+86	5	b 2	GH. H 4 (Gruber at 250° +87° Oct. 22–28)
	129. (123.)	August 22? to October 20	46	+35	12	b 1	GH T 4. SZ. 3 H 3 GH* (*Muscids.*) Gruber at 39° +30° Oct 19
	130	September 1 to October 15	302	+62		c 2	H 3 S 2.
	131.	September 7–15	60	+61	4	c 3	SZ 2 T 2
	132.	October 1–15	57	+61	1	d	H Possibly same as No 131
	133	September 27 1864	17	−10	1	c 1	Prof Herschel. (Well pronounced near θ Ceti.) ?=No 105
	134.	September to October 27	78	+11	3	c 3	S 2. T (?=No 135)
	135	August 29 to October 31	74	+27	11	b 2	GH* SZ T 6 S. 2 Tacchini (GH* at 68° +17°, Sept) Possibly continued at No 210
	137 (201)	September 17 to November 25	84	+48	8	b 1	GH. SZ. 3 T S H A S Herschel. *Aurigids* I.
	138.	August 7 to October 31	40	− 6	8	b 2	N S 4 T 3 *Eridanids*
	138*a*	October 7–14	43	+ 3	4	c 3	T 4 Probably = No 138.
	140.	September 25? to October 24	247	+68	3	c 2	SZ S GH*
	141	October 3–21	136	+46	2	c 2	GH T
	142.	September 25? to October 28	105	+27	5	c 1	GH* T SZ Denning Gruber Herrick, 1839 Max 23 Oct. *Gemellids*
	144. (160)	October 15 to November 6	342	+56	4	c 2	H S ? GH* (GH* = 325° +60°)
	199	October 1 to November 13	352	+34		c 3	SZ. 2 S
	145	October 16–31	21	+41	2	d	H GH* Possibly a pseudo-radiant
	146.	October 18–29	287	+47	[illegible]	c 3	GH GH*
	147	September 1 to October 12	129	+26		c 3	GH* T SZ (Since 1869)
	148	October 11 12 1865	93	+21	2	c 3	T
	152.	October 5–27	87	− 3	[illegible]	c 1	T 6 S Maximum Oct 13
	152*a*.	October 12–13	77	−10	2	d	T Probably connected with No 152
	149	October	145	+18	[illegible]	c 3	T S (? an early subradiant of the *Leonids* No 171)
	150.	October 13 to December 8	28	+ 8	5	c 2	T 2 S GH* Backhouse at *o* Piscium, Oct 30 1874.
	151 (161)	October 19 to November 13	312	+48	2	c 3	S (At 316° +44° Oct. and 307° +53° Nov 1 13) Max. October 23
	153 (155)	October 8 to November 15	107	+ 7	7	c 1	S 2 T 5
	154	October 19 to November 20	34	+23	4	c 2	T S GH* Denning Possibly = Nos 150 or 129
	154*a*	October 17 24	21	+22	3	c 2	Gruber (Radiants I VII. XIII.)
	156	October 21 to November 30	60 (55 +16 to 65 +24) (58 +19 Gruber)	+19½	11	a 2	GH GH* SZ. T 6 H Denning Wood, Herschel Backhouse Denman (Greenwich 55° +25° Nov 13) Well marked shower Radiant perhaps double (Tupman) or elongated? *Taurids*, I.

Table of Radiant-positions and Duration of Meteor-showers (*continued*).

I.	II.	III.	IV	V	VI.	VII.
157.	October 5 to November 13 ?	89	+15	15	*a* 2	GH GH* SZ 3. S 2. T 8 A well-marked shower Herrick, 1839, Oct 16–25, at 99°, +26° (? No 141). Prof Herschel, Oct 18–20, 1864–65, at 90°, +15° (γ Orionis) *Orionids* Gruber at 93°, +18°
207.	October 18–23	2	+25	2	*c* 2	Gruber, Vienna, 1848, 1849, 1867, 1868, 1870 ‡.
208.	October 28 .	94	+71	2	*c* 3	Gruber, SZ. (89°, +71° and 110°, +73°)
158.	October 31 to November 30 ?	130	+ 5	3	*c* 2	GH. T (134° +6° and 124½°, +4½°)
195.	October 18 to November 14	43	+26	2	*c* 2	GH. GH*. (=R 3 radiant)
196.	October .	115	−10	1	*d*	S.
197.	October . .	40	−30	1	*d*	S. 1.
191.	October 18–27	347	+14	1	*d*	S. Possibly connected with No 109
194.	October 28 to November 26	159	+56	1	*c* 2	GH* Perhaps connected with No 176
165.	November 7–27	160	+40	2	*c* 1	T Confirmed by Denning at 155°, +36°, Nov. 20 to Dec 5 from 17 meteors.
162.	November	68	+65	2	*c* 3	S Denning Possibly a continuation of No 139.
159.	November 9	61	+42	1	*d*	SZ.
163.	November 7	101	+ 7	1	*d*	T.
164.	November 6 .	57	− 9	1	*d*	T (Confirmed Nov 1–3, 1872)
166.	November 1 to December 9 ...	286	+57	4	*c* 1	GH. H. S. Clark.
167.	November 13–14	33	+40	1	*d*	Denza. (Perhaps a pseudo-radiant of 159, 172, and 195)
168.	October 15? to December 14 .	46	+55	5	*b* 2	GH H. 2. SZ GH*
169.	November 14..	188	+37	2	*c* 3	Prof Herschel, 1870 7 meteors with good radiation. Confirmed by GH* and Denning
169*a*.	November 24–25 .	205	+45	2	*c* 2	Denning, 1876 From 13 meteors Confirmed by Corder
170.	November 10–25	121	+42	3	*c* 3	GH*. SZ. 2.
171.	November 11–15 .	149	+23	20?	*a* 1	Omnes' *Leonids* Max 1833, 1866, Nov 14, A.M., with 33¼ years' period Connected with Comet I 1866
172.	November 24 to December 7?..	25	+43	35	*a* 1	Prof. Herschel &c., 1872. *Andromedes*, No II Observed in 1798 and 1838, Dec 6–7 Great shower Nov 27, 1872. Present extent of shower's duration uncertain. =Biela's Comet (A16 of GH.).
172*a*.	November 14 to December 19	20½	+60	6	*b* 2	GH* H. 3. Different from No 172.
173.	September 15? to November 15?	14	+57½	2	*b* 2	GH. S Possibly connected with 172*a*. Schmidt, 5°, +53°, for Oct. 22–28.
181.	November 25 to December 7 ..	150	20	2	*c* 3	SZ. S.
174.	November 10 to December 25 .	79	+ 7	3	*c* 2	S. 2. T. Possibly No. 134 continued
175.	November 10 to December 20 .	135	+40	11	*b* 2	SZ. 5 S. Masters, 1867. Gruey, 1874. Corder, 1876, at 131°, +44°. Denning, GH*.

176. (10)	November 4? to January 6	157	+60	5	c 1	GH SZ. GH* T (? radiant elongated) Clark, 1872.
177	November 10 to December 15	201	+85	4	c 2	H 2. S GH*
181a.	November 25 to December 12	150	− 1	2	c 3	Denning 1876 Confirmed GH* Dn. 148° +2°
209.	November 20–28	211	+20	1	c 2	Denning 1876 At α Bootis
210	November 22 to December 7	80	+23	1	c 1	Denning 1876. — Comet II. 1702? From 18 meteors. A M *Taurids*, II.
178	November 23 to December 27	105 (109	+32 +25 Gruber)	14	a 2	GH SZ 2 T S 3. GH* Clark, Wood, Denning Serpieri, Waller Greg. *Geminids.* An important shower possibly aerolitic, with max about 9–12 Dec Radiant-area probably elongated 95° +25° to 110° +25° Bluish white, sometimes *green*, trained *meteors*
178a.	December 10–13 1873 December	95 (85	+24 +35 Schmidt)	1	c 3	Serpieri and Lorenzoni noticed a centre of radiation at 95° +24° (? = No 178)
201 (136?)	November 15 to December 15	83	+45	3	c 2	GH* (= G *a* of 1867 B A Atlas G & H) gives swift white meteors aerolitic and a different radiant from No 178 but the epochal maxima are both about Dec 9–12 Possibly a continuation of No 136 which commences in September *Aurigids* II.
202.	November and December	87	−36	2	c 2	N (= Heis and Neumayer's Ω1 and Ω2)
179	November to December 12	180	+59	3	c 3	SZ S Possibly connected with No. 176
179a.	January	241	+70	1	c 3	Denning Distinct from 179b R.A. wrong in Map.
179b.	November 25 to December 20	209	+67	3	c 1	Corder Denning Denza (Map L, not K)
180. (183.)	December 5–25 ?	53	+10	3	c [illegible]	S (41° +12° and 57° +12°) Clark at 59° +1°
181	December	150	+21	2	c 3	SZ S (154° +26° and 146° +16°)
182.	December 9–21	108	+63	3	c	SZ 3
184.	December	182	− 2	1	d	S (? = No 5)
185	December	32	+30	2	c 3	S GH* Dec 5–13
186	December	4	− 4	1	d	S
187	December and January	117	+13	3	c 2	S 2. Confirmed at 109° +10° Nov 20–Dec 21 by Denning and GH*
206	December and January	110	−33	2	c 1	N (= Heis and Neumayer Γ1 & 2) See Br Assoc. Reports, 1868 p 40

‡ For Gruber's observations on October Meteor-showers see Brit. Assoc Report vol 1875 pp 220–223. Prof A. S Herschel's comet accordances with meteoric showers at page 229 *ibid*

Note.—Mr Denning has lately furnished Mr Greg with well-determined meteor epochs and radiants, deduced chiefly from his own recent and from numerous 1872 Italian observations and not included in the above Catalogue viz —at 107° +22° for December and January 295° +53° for January 250° +25° and 262° +47° for January 14 to February 20 236° +11° and 263° +36° for January and February 282° +19° and 142°, +15° for March and April, 206°, −8° for April, 209°, −3° for May 3–15 and at 83°, +24° for February 16 to March 12.

IV. Aërolites.

Several falls of meteorites (one of them of much importance) have recently occurred, detailed accounts of which, and of recent researches on aërolites and on aerolitic meteors, have been collected during the past year by Dr. Flight, and form in this Appendix (see Part II.) a continuation of the similar abstracts contained in last year's Report.

Part I.—*A Review of recent Stonefalls and of Papers relating to Meteorites.*
By A. S. Herschel.

The following falls of meteorites have been placed on record since the date of the last of those which were there described.—

A.D. 1814, — — Gurramconda, near Chittoor, North Arcot, Madras, India.
,, 1875, Sept 14, 4^h P.M. Supino, circ. Frosinone, Italy.
,, 1876, Apr. 20, 3^h 40^m P.M. Rowton, near Wellington, Salop, England (Ironfall).
,, 1876, June 28, 11^h–12^h A.M. Stalldalen, Dalecarlia, Sweden. (See account of this aerolite at the end of this Appendix.)

The following descriptions have also been given of meteoric appearances, presumably aerolitic, of which no further corroborations have hitherto been received.

1875, Feb 10th, Isle d'Oléron, and March 9th, Orleans, France. (See these Reports, vol. for 1875, p. 206) In the French weekly scientific journal 'Les Mondes,' vol. xxxvi. p. 458 (March 25th, 1875), these meteors are described as falls of aerolites. It appears probable from this description that they were detonating fireballs; but of this, and of their possible aerolitic characters, no other evidence has been produced of which the Committee has yet received intelligence.

The following notice of large meteors seen in America in December and January last, by Mr. C. W. Irish, of Iowa City, U.S., although affirming them to have both been of the detonating class, does not distinctly pronounce them to have been accompanied by falls of aerolites; but one at least of these fireballs produced a very loud explosion. "In the last week (the 27th) of December, 1875, at 9^h P M, and also in the first week of January, 1876, large meteors traversed the air near the south boundary of this (Iowa) State. One passed near Ringold Co., south-easterly; the other passed over St. Joseph, in the State of Missouri, travelling eastwards; and both came to the earth, I think, very brilliant and noisy. It is stated, in the 'Kansas Chief' of December 30th, that after a lapse of 2 minutes after the disappearance of the meteor of the 27th, a sound like the discharge of a heavy cannon was heard, or rather one loud explosion followed by a lighter one. It jarred houses and rattled windows."

From the 'Scientific American' of August 12th, 1876 (p. 98), Mr. Wood communicates the following apparently authentic record of a recent fall of an aërolite in Kentucky, U.S., no meteor, however, being described, and no other details of the occurrence having yet been received:—"The Louisville 'Courier Journal' states that on July 18th (1876), at 4^h A.M., Mr. White, watchman of the Whiteford engine-house, whilst on duty, was startled by a loud report, like that of a pistol, and instantly following some heavy substance fell into the street a few feet distant Mr White searched, and found imbedded in the ground a stone of the appearance of dark flint, weighing about two pounds The stone was broken to pieces, and examined during the day by several scientific gentlemen, who pronounced it genuine meteoric substance The probable solution is that the explosion occurred at a greater distance than was supposed, and that this was but a small fragment of a large aerolite '

To the many valuable essays on the physical characters of aerolites with which Professor Maskelyne has from time to time enlarged the extent of our knowledge of the real nature of these bodies, and to the unremitting zeal with which he has collected in the British Museum a series of authentic specimens of meteorites not excelled in any other national mineralogical collection, we owe many of the most interesting discoveries and conclusions of scientific importance regarding the probable history of meteorites which have been arrived at in recent years Some outline of the progress that has been made in these investigations was given in the concluding paragraphs of last year's Report but a very valuable summary of the existing state of knowledge on the composition, structure and probable history of meteorites has appeared in a series of papers* published during the past year by Professor Maskelyne, entitled "Some Lecture Notes on Meteorites" to which, as they contain a most instructive review of the many points of information accumulated during a prolonged period of successful and diligent research, the Committee has especial satisfaction (while noticing in this Report the principal contributions to aerolitic science during the past year, notable additions to which were made in our own country) in being able to refer These useful Lecture Notes contain in a few condensed and readily accessible pages the mature results of almost numberless scattered treatises and memoirs, and besides the certain basis of instruction which they offer on the ordinary features of composition, structure, and typical characters of meteorites, and of the circumstances which attend their fall, a store of useful hints and germs of future theories are thrown out regarding the extra-terrestrial conditions of rock-formation on distant astronomical bodies from which these strange fragments are derived In connexion with the discoveries (and especially with the views advanced by Mr Lockyer to explain them) of the spectroscope regarding the selective arrangement and definite elevations of certain elements forming the ordinary ingredients of terrestrial rocks in the outer layers of the sun's atmosphere, the low degree of oxidation which invariably characterizes the constituent minerals of meteorites appears, among the conjectures to which Professor Maskelyne draws attention, no longer to be a singular peculiarity of the parent bodies from which they were projected, but a condition of their surfaces which corresponds exactly with the common assumption of their small dimensions, usually regarded as a necessary supposition to account for the projection and liberation of aerolites from the attraction of those distant spheres by forces of ordinary eruptive violence Such views of the arrangement and concentration of the elements by gravity in condensing cosmical masses, tending, in the order of superposition of their densities, to eliminate as much oxygen and other light-atomed elements as they contain towards the surfaces, if, as appears very probable, they should soon be confirmed by a more perfectly discriminating scrutiny of the sun's atmosphere with the spectroscope, will link together more closely than before the evidence which the spectroscope affords, and which has independently been gathered from a minute examination of meteorites, that the materials and the laws of aggregation of the elementary substances constituting the largest and the smallest suns and planets are essentially the same, only differing very strikingly from each other in their scale. Conditions which we notice on the sun and on our own globe we may regard as having in all probability once presided over the process of condensation of every planet from a state of vapour, and as having notably collected on the surfaces of the small meteorite-yielding planetoids, in exact proportion to their size, less oxygen than we find existing on the surface of the earth. Passing over many valuable pages of descriptive matter in the 'Notes,' containing exact accounts and appropriate discussions of many new as well as formerly narrated particulars and observations, it should be stated that the explanation given in one of the first paragraphs of the first article in 'Nature' (*loco sup. cit.* p. 487) of the characteristic pittings of the surfaces of meteoric stones and irons, supposing them to arise from exfoliation of pieces of the stone or iron by the sudden expansion of the material produced by heat, is set aside in a later paper by Professor Maskelyne in favour of a far more natural and more probable hypothesis, the leading points of which will be presently described.

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* 'Nature,' vol. xii pp 485, 504, 520 (September 30 and October 7 14 1875)

The meteoric fall of the greatest interest during the past year was that of an aërosiderite, or piece of metallic iron, which fell in Shropshire, eight or ten miles north of the Wrekin, on the 20th of April, 1876. Rain was falling heavily, unaccompanied by lightning or thunder, and the sky was thickly overcast for some time before and after the hour, 3^h 40^m P.M., when the event took place. At that time a strange rumbling noise was heard, followed by a startling explosion like a discharge of heavy artillery, audible over an area several miles in extent among the neighbouring villages of Shropshire. The meteorite was found about an hour after this occurrence by the tenant of a grass field, near the town of Wellington, Mr. Brooks, who had occasion to visit the spot, and observing the ground to have been disturbed, probed the hole which the meteorite had made, and discovered it at a depth of 18 inches below the surface. Some men at work at no great distance had heard the noise of its descent, but without being able to indicate the exact place or its direction. The hole was nearly perpendicular, the meteorite having entered the ground almost vertically in a north-west to south-easterly direction, and when found it was still quite warm. It weighs 7¾ lbs., and is a mass of metallic iron irregularly angular, although all its edges appear to have been rounded by fusion in its transit through the air, and, except at the point where it first struck the ground, it is covered with a thin black pellicle of the magnetic oxide of iron. The surface is somewhat pitted or marked with slight depressions, one of which occurring in a fissure of the mass affords some instructive evidence of the causes of their formation. The exposed metallic part of the surface exhibits crystalline structure very clearly when it is etched. The meteorite was first exhibited publicly at a local bazaar, held in Wolverhampton, and afterwards at a meeting of the Natural History Society of Birmingham, by whose representations to the agent of the Duke of Cleveland, and by the Duke's consent, in whose property it fell, it was presented to the British Museum. It is only the seventh aërosiderite, or meteoric iron, of which the fall has been witnessed[*], although upwards of a hundred iron masses have been discovered in different parts of the globe, which are undoubtedly meteoric, and two such have been found in Great Britain The falls of eight stony meteorites have been recorded in this country, of which the last happened at Killeter, in Ireland, on the 29th of April, 1844 A Section of the Rowton siderite for analysis will shortly be made, and the foregoing description of the meteorite, and of the circumstances attending its fall, are extracted from an account of the occurrence of the aerosiderite by Professor Maskelyne, in 'Nature' of July 27th, 1876 (vol xiv p 472)

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[*] For a list of the earlier known examples of such ironfalls, see these Reports (vol. for 1875, p. 246).

Regarding the origin of the remarkable pittings of the surfaces of aerolites and aerosiderites, an opinion was lately expressed and advocated by Daubrée *, that in their flight through the air they undergo erosion and excavation by joint effects of fusion and combustion, assisted mainly by air vortices attacking most violently certain portions of their surface An important paper on this subject, by Professor Maskelyne, was published more recently in the 'Philosophical Magazine' of August 1876 It is true that pittings identical in appearance with those of meteorites are found on the surfaces of certain large grains of powder blown unconsumed from the mouths of the large modern rifled ordnance (excellent specimens of this kind received from Professor Abel and Major Noble having been shown by Professor Maskelyne to Mr. Daubrée in the summer of 1875) but two important grounds for exception, in regard to this explanation, are pointed out by Professor Maskelyne, which must not be overlooked The closest examination of the molten glaze with which, like other parts of their surfaces, the pittings or depressions of meteorites are coated over, shows no indications of verticose action of the air, although stream-lines of the glaze from front to rear are of frequent and conspicuous occurrence The process of atmospheric combination, or combustion, is also rare, if not entirely absent, during the period of most intense operation of the heat, as is shown by particles of metallic iron which are occasionally found imbedded in the glaze, and even by cases where the highly oxidizable mineral Oldhamite (calcium sulphide), occurring in spherules in the Busteo meteorite, is glazed over equally with the Augite, without offering any signs of combustion or of the production of cavities where they are exposed On the other hand, the readier fusibility of some constituent minerals of meteorites appears to determine the formation of depressions of the surface where they present themselves and among the magnesian silicates which form the principal materials of stony meteorites, it appears that the more ferruginous varieties are somewhat more fusible than the more purely magnesiferous silicates, which, with minor assemblages of other minerals, enter, in very various proportions, into the composition of the stony masses of aerolites If the entire process of surface-melting and abstraction which meteorites undergo is thus correctly represented, the question of the amount of fracture and division into separate parts which they may suffer by their collision with the atmosphere is one which is yet undecided, and many difficulties beset the inquiry if meteorites are single bodies or if, as numerous examples appear to testify, they sometimes enter the atmosphere in swarms An important dissertation on this question by F Mohr appeared during the past year in Liebig's 'Annalen'†, and a paper by Von Tschermak (of which a brief abstract was presented in last year's Report), on the same subject of the probable origin and of the original forms of aerolites, is now translated *in extenso* in the Supplementary No. for June 1876 of the 'Philosophical Magazine.'

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* 'Comptes Rendus,' April 24th, 1876

† Vol clxxix. pp 267–282.

Part II.—*Accounts of Aerolites and Aerolitic Meteors, and Abstracts of recent Researches on them.* By W. Flight.

1875, February 12th, 10.30 P.M. (Chicago time).—Iowa Co., State of Iowa*.

The conclusions arrived at by Wright, on examining the gases occluded by the iron of these meteorites, have been referred to in the Report (B A) for 1875, p. 240. He considered that the stony meteorites were distinguished from the iron ones by having the oxides of carbon, chiefly the dioxide, as their characteristic gases instead of hydrogen. This theory has been called in question by Mallet, who refers to his examination of the gases of the iron of Augusta Co., Virginia, where the ratio of the oxides of carbon to hydrogen is 4·3, and to his having pointed out in 1872 that hydrogen could no longer be regarded as *the* characteristic gaseous ingredient of meteoric iron. In his paper of that date he stated that although it might be assumed that carbonic oxide would be the original form in which the gaseous carbon-compounds existed in the iron, and that it broke up at the temperature of the experiment into carbon retained by the iron and into carbonic acid, yet in view of the steady decrease of the quantity of the latter gas which was evolved as the experiment proceeded, it seems more likely that a larger amount of carbon originally existed in the higher state of oxidation. Mallet considers that, when all the circumstances of the experiment are considered in each case, Wright's conclusion cannot be sustained.

In a paper dated some months later, Wright replies to Mallet's criticism. He states that he only meant this expression of opinion to be tentative, but that the results of further work completely justify the conclusion at which he had arrived. He has re-examined the gases of the iron of this meteorite, and examined those of the iron of some other stony meteorites, such as Ohio, Pultusk, Parnallee, and Weston, and finds that not only do the stony meteorites give off a much larger volume of gas at low temperatures, but the composition of the gas in all the cases studied is quite different from that evolved from meteoric iron. In no case among the results obtained with the alloy is the amount of carbonic acid greater than 20 per cent. at 500°, nor than 15 per cent. of the whole quantity evolved, while in every case but one the volume of carbonic oxide is considerably larger. In the chondritic meteorites, on the other hand, the percentage of the latter gas is conspicuously small, while the carbonic acid constitutes more than half the total gas evolved below a red heat, except in the case of the meteorite under consideration which fell at Iowa, and here the percentage is not much less, especially if we reject the numbers representing the amount obtained by a second and long-continued application of a red heat. At a temperature of about 350° it constitutes from 80 to 90 per cent. of the gaseous products, and at 90° it forms more than 90 per cent. of the gas evolved. The hydrogen, on the other hand, progressively increases in quantity with the rise of temperature, and is the most important constituent of the first portions removed at a red heat. The form in which the carbonic acid is occluded is a problem which he cannot at present solve. That it is actually absorbed appears to be certain.

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* J. W. Mallet, 'Amer. Journ. Sc.' 1875, vol. x. p. 206; N. R. Leonard, *ib.* vol. x. p. 357; A. W. Wright, 'Amer Journ Sc.' 1876, vol. xi. p. 253; "An Account of the Detonating Meteor of February 12, 1875," by C. W Irish, Iowa City, 1875, Daily Press Job Printing Office, Dubuque Street, M. Delafontaine, Bibliothèque Universelle,' October 1875, p. 188; G. A Daubrée, 'L'Institut,' 1875 (Nos 105–122), p. 138, C. W. Gümbel, 'Sitzungsber. Ak. Wiss. Munchen,' 1875, vol. v. p. 313.

That it has been taken up from the atmosphere has been proposed He finds, however, that the iron of the Iowa meteorite contains no more carbonic acid now than it did at the time of its fall

Leonard gives a detailed account of the appearance presented by the meteor, which is stated to have been seen throughout a region 400 miles from S W to N E, and 250 miles in breadth The stones vary in weight from a few ounces to 74 lbs and the aggregate weight is 500 lbs the area over which they were scattered appears to be 7 miles in length and 4 miles at its greatest breadth A plan of the townships included in this area is given in Leonard s paper, and it shows where the chief stones fell By reason of the frozen condition of the ground at the time of the fall, and the low angle of descent it appears probable that almost all the fragments which fell have been secured The velocity of the meteor has not been satisfactorily determined it appears probable that during the last 60 or 70 miles of its course it travelled at the rate of from 6 to 7 miles per second

An interesting pamphlet by Mr Irish C P deals with the appearance presented by the meteor He has incorporated in his paper a number of letters received from observers stationed over a wide area, describing their impressions as to its altitude velocity and appearance and he has given a drawing of the meteor and prepared a map of the district showing the projection of its path through the air I learn by a recent letter from Mr Irish that two blocks one weighing 72 lbs , the other 18 lbs , which evidently formed one and the same mass which was disrupted during the descent have since been found and the aggregate weight of the stones now collected cannot be less than 700 lbs I am also indebted to Mr Irish for six excellent photographs of the Iowa stones, sixty-seven in number, which form the collections of Prof Hinrichs Mr J P Irish and himself They were taken by Mr Thomas James, of Iowa city and are in the very best style of photographic art

Prof Gumbel, of Munich, has recently published an interesting paper on the characters of this meteorite He finds the crust to possess a deep bottle-green or brownish red colour and to possess in polarized light all the characters of an amorphous glass-like mass When a fragment is heated it turns of a dark brown colour, like that noticed by him in the eruptive rocks of the Fichtelgebirg, and he regards this change as a safe indication of the presence of olivine

The composition of the stone is found to be

Meteoric iron	12 32
Troilite	25
Silicate decomposed by acid	48 11
Silicate, not acted upon by acid	34 32
	100 00

The silicate decomposed by acid is an olivine, having the formula $2(\frac{2}{3}MgO, \frac{1}{3}FeO), SiO_2$, and the insoluble silicate, which has been regarded by Dr Lawrence Smith as pyroxene, gave the oxygen ratios—silicic acid = 29 68 , bases = 10 29 It appears not improbable that in this case the silicate was not completely decomposed during analysis

The paper is illustrated with an interesting plate of a microscopic section showing olivine, augite, meteoric iron, chromite, troilite, particles of a reddish hue which resemble garnet but which doubly refract light and exhibit optical characters which will not allow of their being identified with nosean, and chondra showing fibrous, radiate, and granular structure, as well as others which evidently consist of olivine, and some which are opaque and finely granular. The meteoric iron has a hackly angular structure, and has the appearance which it would present if reduced to the metallic state in the position which it at present occupies.

1875, December 27th, 9 P.M.—Kansas

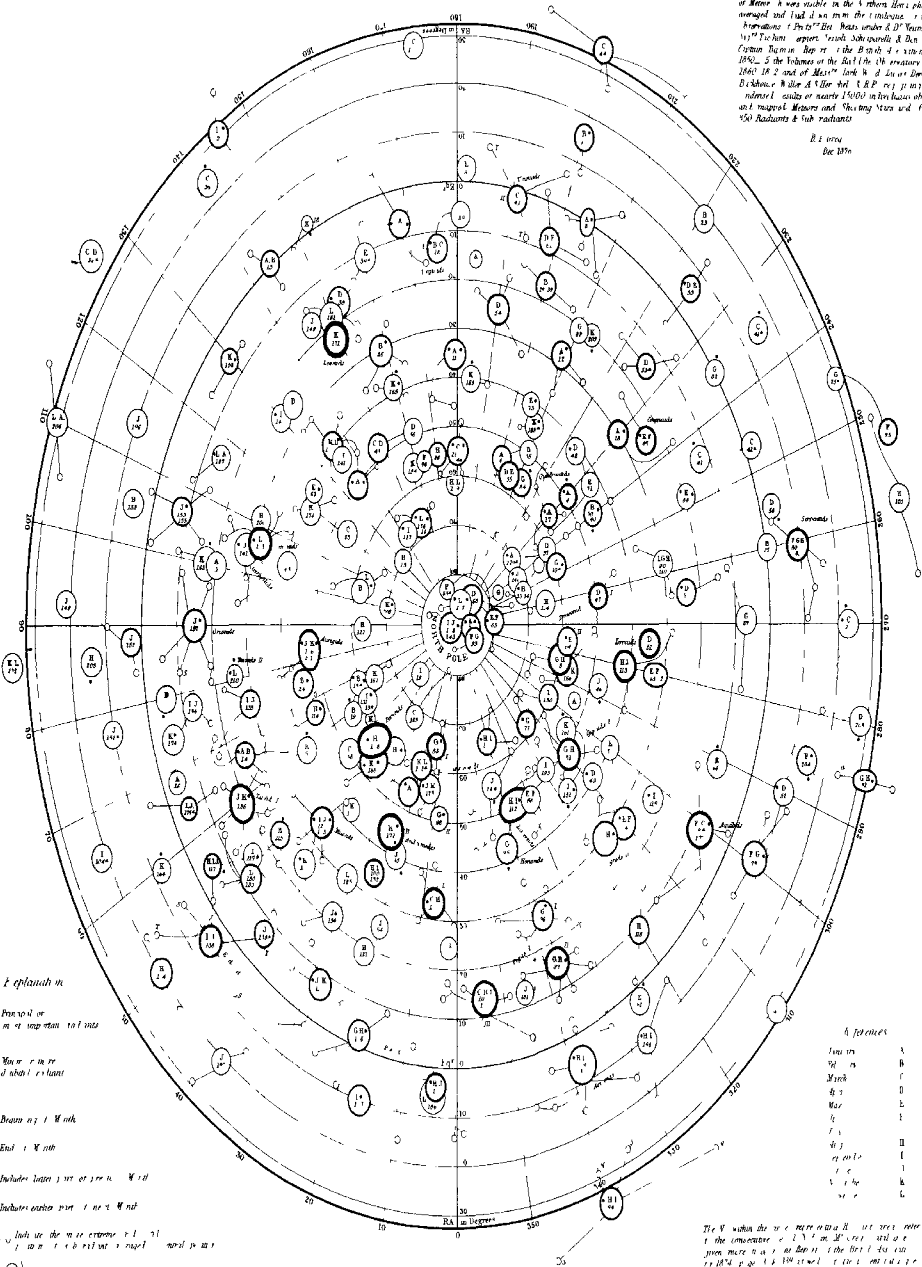
I have to thank Mr. Irish, C.E., of Iowa City, for two cuttings from newspapers (the *Kansas Chief* of December 30th, and the *Kansas Evening Post* of December 29th) recording the fall of a detonating meteor of the above date. It traversed the heavens in a direction from N.W. to S.E., leaving a lurid streak in its wake. The whole heavens were lighted up, and "made all out of doors almost as light as full moonlight." The meteor was of the usual whitish-red colour, and when it exploded the fiery fragments were scattered in all directions. "Perhaps two minutes later, and after all appearance of the meteor had disappeared, the sound of the explosion came like the discharge of a heavy cannon, or rather one loud explosion, immediately followed by a lighter one like an echo. The explosion jarred houses and rattled windows. The size of the meteor and the terrible force of the explosion may be imagined from the fact that the distance was so great that it required about two minutes for the sound to reach the earth, and the concussion was so plainly felt and heard at that distance. The phenomenon was witnessed over a large extent of country." An observer, writing from Fort Leavenworth, states that it appeared to have its origin in the constellation Cassiopeia, and its course was due east. Mr. Irish states that he has made every effort to secure possession of the meteorites which must have fallen, but has been unsuccessful. The time of flight is estimated to have been from 12 to 15 seconds.

1875, December 27th, 9.20 P.M.—State of Missouri, U.S.A.

I am indebted to Mr. Irish, C.E., of Iowa City, for an interesting description of this detonating meteor, as well as for a map, on which he has traced its course. The point where it was first seen in the zenith is at Thayer, in Nebraska, near the borders of Kansas, and about 120 miles W. of the Missouri river. It was seen by him at Iowa City first as a small meteor, which rapidly became brighter, and was hidden from view when at an altitude of about 40° by a building; at this moment it gave out a very brilliant quivering flash of light, which illuminated the whole heavens. It appears from Mr. Irish's map to have been seen over a wide area, from Stillwater in Minnesota on the north to Buffalo in Missouri on the south, and as far west as the shores of Lake Michigan. Near the termination of the flight sounds were heard: over Archer, in Nebraska, a rushing roaring sound, as of a mighty wind, was noticed; at St. Joseph, in Missouri, the first distinct explosion was remarked, and between that town and Livingstone Co. frequent and very heavy detonations occurred. In the last-mentioned district, and at places as far as 60 miles distant, numerous red fragments were seen to fall. He says, "I have had several persons looking for the meteorites where the fall must have taken place; but the whole district is covered with dense forest, and is mountainous and broken, and the ground was very soft from the long-continued rains preceding the fall, so that no fragments have been found. All the observers of the final explosion agree that the great bulk of the material was thrown upward and backward upon the course of the meteor, as the arrow-pointed dots in my sketch indicate. The luminous appearance continued in sight for 15 minutes."

Diagram or Key Chart ([illegible]) showing the positions in R.A. and N. Decl. of [illegible] Radiants of Meteors which were visible in the Northern Hemisphere averaged and laid down from the [illegible] and observations of Profs. Heis, Weiss, [illegible] & Dr Neumayer, Sig^rs Tacchini, Serpieri, Zezioli, Schiaparelli & Denza, Captain Tupman in Reports of the British Association 1850–75, the Volumes of the Radcliffe Observatory 1860–1872 and of Mess^rs Clark, Wood, Lowe, Denning, Backhouse, Miller, A. S. Herschel & R. P. Greg, giving the condensed results of nearly 15000 individually observed and mapped Meteors and Shooting Stars and of nearly 450 Radiants & Sub-radiants.

R. P. Greg
Dec 1876



Explanation

Principal or most important Radiants

Minor or more doubtful Radiant

Beginning of Month

End of Month

Includes latter part of previous Month

Includes earlier part of next Month

Indicate the more extreme [illegible] positions of the Radiant [illegible] normal points

Indicates a probable or suspected connexion between two Radiants e.g. Nos. 4 and 56 in the Map

References

January	A
February	B
March	C
April	D
May	E
June	F
July	
August	H
September	I
October	J
November	K
December	L

The Nos. within the circles representing Radiants are [illegible] refer to the consecutive [illegible] in Mr Greg's [illegible] given more [illegible] the Report of the Brit. Assn. for 1874, pages [illegible] 134 as well [illegible] the average extent [illegible]

E. [illegible]

1876, January 5th, 10.30 P.M.—Iowa and Missouri.

This meteor, according to Mr. Irish's letter and accompanying map, was witnessed over an area extending from Cass, in Iowa, to Grundy, in Missouri. It appeared to descend almost perpendicularly, and was a very brilliant meteor, and a very noisy one also. A series of reports twenty-two in number were heard during its transit from Cass to Grundy. The rumbling thunder of its artillery, together with its flashes of brilliant light, brought people from their beds with an apprehension that the great Civil War had broken out afresh. Its time of flight over the area indicated was not more than five seconds, and the light it emitted is said to have equalled that of noonday. None of the meteorites which must have fallen have been found, for the reasons already referred to when speaking of the detonating meteor of December 27th.

1876, January 31st, 5.30 P.M.—Louisville, Kentucky.

Dr Lawrence Smith, of Louisville, observed a magnificent meteor traversing the heavens on the afternoon of the above day He first saw it at an altitude of about 60° above the horizon, and it disappeared from view behind some houses at an elevation of about 20° Its direction appears to have been from N W. to S E, and the angular magnitude about one sixth that of the disk of the moon. It was seen over an area 120 miles in diameter. A number of observers witnessed an explosion which took place when the meteor was about 10° above the horizon; all the fragments disappeared instantly, except the largest, which also became invisible before it reached the horizon. One or two of the eye-witnesses think they noticed a whizzing noise, and at the time of bursting heard the explosion. No fragments of a meteorite have yet been met with; but it is the opinion of Dr. Smith that they fell about the range of the Cumberland Mountains in Kentucky, or in the north-east of Tennessee.

1876, April 7th (evening).—Eperjes, Hungary *.

A fireball passed over Eperjes 8° [? E. or W] from the meridian, and detonated at an altitude of 38° above the horizon It exploded with a very loud noise, and broke into numerous fiery fragments.

1876, June 28th, 11-12 A.M.—Stalldalen, Dalecarlia, Sweden.

A meteor traversed a part of Central Sweden in a W.N.W. direction, and was plainly visible in the very bright sunshine. It was observed at Stockholm and at Sodermanland; at 13 English miles S.W. of Linkoping it was seen first in an N W. direction, and at a considerable altitude, and it descended almost to the horizon in the west. A loud whistling noise was heard in the air from E. to W., followed by two sharp reports, and others less loud resembling thunder. The fall of the meteorites was witnessed by eight or ten persons, and three or four fragments have been secured by Dr. Lindstrom. The largest, about the size of two fists, weighs 4½ skalpund [1 lb. av. = 1·068 ltt. or skalpund]. Stalldalen is a station on the Swedish Central Railway, on the northernmost part of Örebrolän. Some of the meteorites which fell in water have been lost.

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* Egyetértés és Magyar Ujsag. Budapest, April 18, 1876.

Report on the Rainfall of the British Isles for the years 1875–76, *by a Committee consisting of* C. BROOKE, *F.R.S.* (*Chairman*), J. F. BATEMAN, *C.E.*, *F.R.S.*, ROGERS FIELD, *C.E.*, J. GLAISHER, *F.R.S.*, T. HAWKSLEY, *C.E.*, The Earl of ROSSE, *F.R.S.*, J. SMYTH, Jun., *C.E.*, C. TOMLINSON, *F.R.S.*, G. J. SYMONS (*Secretary*).

IN accordance with the resolution of the Association, the Rainfall Committee, originally appointed in the year 1865, now present their final report.

They gave in the report presented at Bristol in 1875 a condensed account of the contents of their previous reports.

This year they present the various tables and explanatory remarks upon them which are necessary to complete the work up to the present time, excepting that referred to in the 7th following paragraph.

The tables are as follows, namely:—

I. Examination of Rain Gauges.
II. Rainfall of the years 1874–5.
III. Monthly returns from new Irish stations.

Examination of Rain Gauges in situ.—Appended to this report are the results of the examination of 26 rain gauges visited since August 1875. This brings the entire number which have been visited and examined up to 655. The Committee regard this as a very important subject, and the best guarantee of the records furnished by the observers. They have more than once expressed their conviction that the proper course would have been to appoint a travelling inspector, so that the whole of the gauges might be properly examined; but they have never had adequate funds for the purpose. In fact, the total amount they had been able to devote to it in the 15 years during which the inspections have been going on has only been £210, or an average of exactly £14 a year. The explanation of the smallness of the amount in comparison with the work effected (about 6*s.* 5*d.* per station visited) arises from the fact that it has been almost entirely done by our Secretary, who, as a member of the Association, received nothing for his services but merely repayment of actual expenses, and even these have been materially reduced by the hospitality of the observers.

Rainfall of the years 1874–5.—The usual biennial tables of monthly rainfall at selected stations are appended. Ever since their appointment the Committee have continued these biennial tables, and as Mr. Symons had submitted similar ones for some years previous to their appointment, the entire series embraces 16 consecutive years. Subject only to changes rendered necessary by the removal or death of observers, the same stations have been quoted in each biennial table, and thus these tables contain about 200 perfect records, each extending over 16 consecutive years. Only those persons who are aware of the great importance of continuity in physical researches will fully realize the value of this series, both for physical and hydrological purposes.

The Rainfall of 1874 was slightly below the average, owing to a rather dry spring and exceedingly dry summer. The most remarkable feature of the year was the heavy fall of rain on October 6th, when the *average* fall over England and Wales was slightly above 1 inch in the 24 hours, and the fall at many stations in North Wales and the Lake District was upwards of 5 inches. So heavy a fall over so large an area is a very rare occurrence.

The Rainfall of 1875 was greatly above the average in England (especially in the Midland Counties), and irregular in Scotland and Ireland. A very heavy rainfall occurred in Wales and the southern parts of England on July

14th, the fall in 24 hours exceeded 1 inch at 252 stations, 2 inches at 109, 3 inches at 39, 4 inches at 7, and 5 inches at 3 stations

New Irish Stations—We reported last year the success of our efforts to improve the geographical distribution of Rainfall Stations in Ireland, showed that the gauges started at the cost of the Association had been supplemented by many others established at the cost of private individuals, and gave a map showing the present complete distribution of stations Almost all the observers have proved good ones, and, as the table shows, the returns have been forwarded with regularity The period is too short to yield precise results, but a good system has been inaugurated and is in full operation

At the commencement of this report it was stated that there was one very important exception to the otherwise satisfactory completion of the work up to the present time This exception is the classified list of stations and the results of the "position-returns" which we intended to have incorporated therewith In 1865 we published a complete list of every station in the British Isles at which rainfall observations were known to have been made, giving the observers' names, the height of the stations above mean sea-level, the epoch of the observations, and various other details Owing to the large development of rainfall work during the subsequent 10 years, the list has become very imperfect, and the Committee have been actively engaged in the preparation of a revised list In addition to the details previously given, the list was also to have contained other most valuable information The "position-returns" obtained from the various stations, and which have been mentioned in previous reports, were to have been summarized and the results indicated by symbols affixed to the stations in the classified list and references to publications in which the records could be found were also to have been added The classified list of stations would thus have formed a complete *catalogue raisonné* of all the existing rainfall data, and have given most useful information at present non-existent To the great regret of the Committee, the Association declined to publish the portion of this list presented last year, and the Committee have therefore felt compelled to relinquish its completion They the more deeply regret this, as they consider that the publication of this list would have been a fitting termination of their work, and would have redounded to the credit of the Association

Notwithstanding the above most important omission, the Committee feel they have done good service to rainfall work When they commenced their labours, the weakest part of rainfall observations was the defective geographical distribution of the stations This defect has now been very materially lessened By the grants of the Association nearly 250 gauges have been erected in districts hitherto without observations The work done in the inspection of stations has already been mentioned A definite unit has been adopted for the term "rainy day," namely, any day on which one 100th of an inch of rain falls A complete code of rules has been drawn up, so as to secure uniformity of practice among observers The secular variation of the rainfall of the British Isles has been investigated A determination of the average proportion of the total yearly rainfall which occurs in each month has been effected Elaborate observations have been made and discussed on the relative quantity of rain indicated by gauges of various sizes and shapes, and erected at different heights above the ground

To sum up their labours in a sentence, your Committee have aimed—they hope not without success—primarily at obtaining unimpeachable records, and, secondarily, at so discussing and arranging these records as to render them as useful as possible to physical inquirers and hydraulic engineers.

List of Stations supplied with Rain gauges by the British

County	Station	Jan	Feb	March	April	May	June
Cork	Skibbereen	5·92	2·39	1·62	1·53	3·02	3·14
Kerry	Killarney Gap of Dunloe						
	Tralee Godfrey Place	6·77	96	1·79	1·14	3·21	4·02
Tipperary	Tipperary Henry Street	5·90	1·39	1·51	1·24	2·05	3·41
	Nenagh Liska Lodge	(3·96)	89	1·19	99	1·43	3·30
Limerick	Newcastle Baile an Teampul	4·96	1·00	1·65	1·20	1·52	3·96
	Limerick Kilcorna	(3·92)	1·03	1·19	1·96	1·82	4·09
	Janeville Tipperary	7·57	1·83	1·80	1·93	3·29	4·03
Clare	Kilrush	4·21	92	1·11	1·67	1·91	5·06
	Miltown Malbay	4·76	1·31	1·72	1·91	2·76	5·17
	Corofin	(5·11)	96	1·11	1·70	2·78	4·59
Kilkenny	Kilkenny Butler House	4·33	1·27	91	90	1·52	2·78
	Castlecomer	(4·64)	65	1·31	86	68	3·54
King's County	Banagher	3·11	83	99	83	2·11	3·52
Kildare	Naas Ballymore Eustace	(5·47)	3·57	1·32	74	2·00	3·13
Dublin	Rathgar						
Meath	Navan Balrath	(4·75)	1·71	85	84	2·38	3·12
	Kells				1·03	2·09	3·51
Longford	Longford Barracks	4·76	1·21	94			
	Granard Barracks	5·12	1·21				
Galway	Ballinasloe Kilconnell	(6·09)	78	91	1·34	3·15	4·87
Mayo	Westport Rossbeg House	4·78	77	1·75	1·72	2·39	3·64
	Bangor Glenturk Lodge	5·73	1·89	1·82	2·12	4·11	4·64
Sligo	Sligo Ballinful	2·93	1·06	1·23	1·01	2·17	2·94
Leitrim	Carrick on Shannon Drumsna	5·43	1·51	90	1·50	3·63	4·34
	Mohill Dromrahan	4·86	1·23	1·00	99	2·88	2·75
	Carrick-on-Shannon	(3·99)	1·42	79	1·15	2·37	4·36
	Drumkeeran Spencer Harbour	(3·89)	2·06	2·04	1·11	4·35	6·17
	Coll	(7·10)	2·17	2·03	1·52	4·70	7·40
Fermanagh	Irvinestown Eglinton Lodge	(4·89)	1·53	1·59	78	3·61	3·02
Monaghan	Rockcorry	4·99	1·54	1·23	34	2·13	4·00
Armagh	Newtownhamilton	(4·83)	2·00	1·53	54	2·22	4·02
Down	Kilkeel						3·58
	Warrenpoint Summer Hill	4·83	2·57	1·94	52	2·15	4·74
	Newry Newcastle	12·13	2·16	1·45	62	2·50	4·99
	Rathfriland	(5·58)	2·22	1·38	18	1·67	4·52
	Hillsborough Anahilt	3·59	1·41	1·04	13	1·83	3·08
	Newtownards, Model School	4·16	96	1·02	39	1·84	3·32
Antrim	Crumlin	4·29	1·11	1·05	39	1·80	3·40
	Ballymoney Church Street	3·77	1·47	1·63	09	1·83	2·65
	Bushmills	3·15	1·26	1·41	43	2·03	2·98
Londonderry	Londonderry Knockan	(3·64)	87	1·92	81	2·20	2·94
Tyrone	Moy Benburb	3·48	1·41	96	36	1·82	2·91
"	Stewartstown	5·38	1·14	1·26	39	2·01	3·02
	Strabane	4·16	1·15	1·35	70	2·11	2·95
Donegal	Inver Glebe	(3·52)	1·63	1·56	1·59	2·42	4·42
	Carndonagh			1·47	72	3·00	4·00

Association in 1874, and Returns therefrom for 1875 76

July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July
95	2 60	8 30	5 88	4 88	2 73	2 61	5 21	2 59	4 75	10	1 17	2 55
2 53	2 22	8 76	6 76	3 37	4 02	3 03	4 99	4 72	2 89	1 11	2 88	1 75
4 58	2 42	7 84	7 38	3 56	2 30	1 28	4 11	4 93	3 23	73	1 34	1 32
2 13	2 94	5 46	3 48	3 54	2 09							
1 93	3 17	7 12	5 26	4 20	2 3	1 13	4 39	4 82	2 49	1 14	1 46	1 48
2 78	4 80	5 76	4 99	3 34	2 04	96	3 78	4 45	3 37	91	1 45	
3 36	3 60	7 60	2 97	4 13	1 81	1 72	5 27	4 43	2 38	79	2 18	2 03
2 41	1 59	5 98	6 63	2 93	2)7					2)3	1 22	51
3 22	4 24	6 97	4 73	3 5)	3 60	2 36	4 50	3 87	3 26	93	2 56	3 10
1 97	2 74	7 02	5 09	3 43	3 71	2 13	4 87	4 55	2 80	69	1 68	2 71
4 05	2 54	5 66	5 90	2 52	1 73	93	4 63	3 18	2 24	61	1 11	1 26
3 57	1 98	6 13	6 53	4 77	94							
1 81	3 04	5 16	3 95	3 87	2 22	1 26	4 69	3 90	2 26	94	1 70	1 71
3 04	1 31	4 51	3 81	4 14	2 55	1 53	3 98	3 52	2 43	85	2 12	1 61
4 68	1 48	5 47	4 39	(3 93)	2 0	77	3 60	2 54	1 88	67	1 47	1 27
1 58	2 04	5 97	5 31	4 60								
2 28	2 42	5 52	3 79	3 67	3 20	2 07	4 94	4 63	3 02	74	1 68	2 53
2 78	3 18	6 32	4 76	3 18	4 28	3 39	5 34	5 22	2 59	54	2 55	2 35
3 29	2 12	4 81	5 39	5 11	4 24	5 37	6 37	7 13	4 20	2 11	4 99	2 14
3 49	2 68	3 24	4 44	3 56	2 09	1 24	4 47	3 80	2 55	52	1 35	1 11
1 69	4 21	4 49	5 09	(4 81)	3 14	2 25	4 83	4 39	2 69	? 00	? 77	1 59
						2 27	5 55	3 65	2 50	92	1)5	2 33
1 81	3 48	4 04	3 05	3 61	2 33	2 26	5 63	4 09	2 54	47	1 49	1 26
2 43	4 62	5 25	5 04	5 32	3 71							
2 66	6 32	5 77	5 60	6 67	4 80							
2 74	4 50	3 79	5 72	4 49	2 34							
2 60	3 71	4 64	5 83	5 03	2 27	1 65	4 48	3 87	2 18	59	1 41	2 00
3 47	4 60	5 53	5 93	5 55	2 88	1 95	5 05	4 82	2 80	75	2 28	2 02
3 32	4 02	5 29	5 74	4 59	1 63	1 21	3 44	2 28	2 42	40	1 75	1 76
3 20	3 62	8 40	7 86	5 87	3 05	2 26	5 18	3 43	2 67	42	2 48	1 31
3 81	3 06	8 99	7 90	8 96	3 66							
3 51	2 64	6 38	6 28	5 10	2 10	1 60	3 14	2 18	3 09	1 10	2 17	1 40
4 17	3 17	4 22	5 94	4 57	1 54	1 49	4 50	2 71	1 39	44	2 70	2 26
2 55	1 90	4 28	5 19	4 37	2 16	1 34	3 55	2 47	1 56	44	2 69	1 69
3 16	4 52	3 23	4 51	3 88	2 28	1 45	4 20	3 02	2 11	81	2 59	2 42
3 00	3 37	3 32	3 93	4 15	2 13	1 73	3 18	4 32	2 22	84	2 30	2 39
2 05	4 17	3 98	5 19	4 74	2 61	1 67	3 47	4 49	2 03	57	2 97	2 78
2 45	2 90	4 54	4 70	4 86	3 28	2 34	5 44	5 52	2 72	54	2 70	2 39
4 38	4 13	5 26	6 69	6 91	1 95	1 51	5 08	4 64	2 03	33	1 65	1 85
3 10	2 85	3 55	4 92	5 98	2 84	2 09	5 16	4 45	2 11	56	2 90	1 36
1 45	(3 55)	2 13	4 10	4 89	2 97							
2 76	4 98	3 87	5 66	5 40	3 59	2 78	5 39	7 02	4 38	1 27	3 21	2 54
2 40	2 64	4 31	6 31	5 32	3 36	3 03	5 79	4 73	2 81	64	2 93	2 45

EXAMINATION OF

Reference number	Date of examination	COUNTY. Station *OWNER* *Observer.*	Construction of gauge	Maker's name	Time of reading.	Height of gauge.	
						Above ground	Above sea-level.
	1875					ft in	feet
630	Aug 31	GLOUCESTERSHIRE South Parade, Clifton *DR G F BURDER* *Dr Burder.*	X	Negretti & Zambra	9 a m	0 6	192
631	Sept 10	DEVONSHIRE. Martinhoe *REV C SCRIVEN* *Rev C Scriven*	XII	Casella Glass anon	Irregular	1 0	825
632	Sept. 11	DEVONSHIRE Ilfracombe Hotel *ILFRACOMBE HOTEL COMP* *Mr Tatham*	Merely funnel discharging into tube	Anon ..	9 a m	12 6	34
633	Oct 7	DURHAM Raby Castle *G J SYMONS, ESQ* *Mr. Westcott*	X *	Casella ..	9 a m.	1 0	460
634	Oct 7	DURHAM Whorlton *REV A W HEADLAM* *Rev A W Headlam*	III	Anon . ..	..	0 10	400
635	Sept 27	YORKSHIRE Great Ayton, Middlesborough *MR DIXON*	III	Anon	....	4 8	300
636	Oct 26	KENT St Augustine's Monastery, Ramsgate *REV FATHER QUELCH* *Rev Father Quelch*	X	Negretti & Zambra	9 a m	0 6	. . ..
637	Sept 25	DURHAM. Egglescliffe *REV. J HULL* *The Gardener*	XII	Casella ..	9 a m	1 0	80

* This mark denotes that the gauge has a deep Snowdonian rim.

RAIN-GAUGES (*continued from Brit Assoc Rep* 1875, p 111)

Diameters (that marked M = mean)	Equivalents of water		Error at scale point specified in previous column	Azimuth and angular elevation of objects above mouth of rain gauge	Remarks on position &c	Reference number
	Scale point	Grains				
in	in		in			
8·00	1	1250	+·001	S E Tree 45°	In garden at back of house and much sheltered	630
8·00	2	2510	+·002	S S W House 45°		
8·00	3	3750	+·003	N E Tree 40°		
7·94	4	5010	+·004			
M 7·985						
5·00	1	500	·001	Nothing injurious	Gauge only emptied at intervals and monthly total recorded Observer had an 8 in Howard's tube gauge fairly correct suggested its erection and daily record	631
4·98	2	1040	−·010			
5·00	3	1520	−·008			
4·98	4	2000	−·005			
M 4·990	5	2470	correct			
12·00	1	2850	correct		On apex of a summerhouse like thermometer stand in grounds of hotel	632
12·00	2	5700	correct			
12·00	3	8460	+·004			
12·00						
M 12·000						
8·01	1	1300	−·003	N E Greenhouse 22°	In garden N of Castle clear except as noted	633
7·98	2	2550	−·001			
8·00	3	3810	correct			
8·02	4	5050	+·003			
M 8·002	5	6350	correct			
5·08	1	480	+·006	Quite clear in garden E of church	This is evidently a 5 in glass applied to a gauge 5·06 in diameter hence the recorded fall is too large	634
5·05	2	990	+·006			
5·07	3	1450	+·015			
5·05	4	1960	+·015			
M 5·062	5	2450	+·018			
5·02	1	460	+·007	N W Trees 30°	Gauge on a pedestal, very rickety and not well attended to	635
4·98	2	960	+·006			
5·00	3	1460	+·005			
5·00	4	1050	+·006			
M 5·000	5	2450	+·006			
8·01	1	1248	+·002	N angle of Monastery 32°	Good position in garden of Monastery	636
8·00	2	2500	+·003			
7·99	3	3760	+·004			
8·01	4	5050	+·003			
M 8·002	5	6300	+·004			
5·03	1	520	−·005	S one Poplar, 30° S W Acacias 41° N N W House 30° E Lilacs 45° S E Acacia 35°	Gauge on lawn Trees rather too close, but probably not sensibly injurious	637
4·96	2	1020	−·006			
4·98	3	1480	correct			
4·98	4	1980	−·001			
M 4·988	5	2500	−·006			

Reference number	Date of examination	COUNTY. Station. OWNER. Observer.	Construction of gauge	Maker's name	Time of reading	Height of gauge: Above ground	Height of gauge: Above sea level
	1875					ft.	feet
638	Nov	WILTSHIRE [illegible] Gr[illegible] Ma[illegible] [illegible] [illegible]	XII*	Casella	9	1 0	472
639	Nov 3	GLOUCESTERSHIRE [illegible] Asy[illegible] DI[illegible] [illegible] 	X	Negretti & Zambra	9 a.	0 6	
640	Nov 5	HEREFORDSHIRE R[illegible] Place, Hereford E. J. [illegible], ESQ. E. J. [illegible], Esq.	X		9	6 0	188
641	Nov 5	HEREFORDSHIRE [illegible], Hereford [illegible] A. CHAPMAN, ESQ., M.D. T. A. Chapman, Esq., M.D.	III	A[illegible]	9 a.m.	1 3	
642	Nov 4	HEREFORDSHIRE The Grange, R[illegible] H. SOUTHALL, ESQ. H. Southall, Esq.	III	A	9 a.	1 0	200
643	Nov 8	MERIONETH Rh[illegible] MAJOR MATHEW M. O. Jo[illegible]	III	Casella	9 a.m.	10 0	1100
644	Nov 9	CARNARVON Warwick House, Llandudno DR. NICOL Dr. Nicol	X	Negretti & Zambra	9 a.m.	1 0	
645*	Dec 20	NORFOLK Hillington School REV. H. FFOLKES Rev. H. Ffolkes	XI	Negretti & Zambra	9 a.	3 6	
646	Dec 20	NORFOLK Hillington Rectory REV. H. FFOLKES Rev. H. Ffolkes	X	Negretti & Zambra	9 a.	1 0	

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* This mark denotes that the gauge has a deep Snowdon rim.

RAIN-GAUGES (*continued*)

Diameters (that marked M = mean)	Equivalents of water		Error at scale point specified in previous column	Azimuth and angular elevation of objects above mouth of rain gauge	Remarks on position &c.	Reference number
	Scale point.	Grains				
in	in		in			
4·98	1	500	correct	Clear	In meteorological enclosure 30 feet from nearest (low) building	638
5·02	2	990	+·001			
4·97	3	1480	+·003			
5·08	4	1980	+·002			
M 5·012	5	2470	+·004			
7·75	1	1350	−·007	Fair exposure	Gauge had been struck by a mowing machine and very much indented	639
8·02	2	2600	−·007			
7·98	3	3850	−·006			
8·03	4	5040	−·003			
M 7·945	5	broken				
8·01	1	1290	·002	W N W House 22° S E Tree 33°	In small garden in rear of house Gauge fixed in a box upon a post	640
7·99	2	2540	correct			
7·99	3	3790	+·001			
8·01	4	5020	+·004			
M 8·000	5	6300	+·004			
4·92	1	490	correct		Perfectly clear on open lawn	641
5·00	2	980	correct			
5·02	3	1480	−·003			
4·92	4	1980	−·005			
M 4·965	5	2470	−·005			
5·02	1	500	−·001	N Tree 34° N W Tree 38°	On lawn good exposure except as noted	642
5·00	2	970	+·004			
4·99	3	1470	+·004			
5·00	4	1980	+·001			
M 5·002	5	2460	+·004			
5·06	1	500	−·001	Clear	In angle of a stack of slates in the best position the works afford	643
4·98	2	990	correct			
5·00	3	1480	+·002			
4·97	4	1980	+·001			
M 5·002	5	2480	correct			
7·93	1	1300	−·002	N Tree [illegible]0° S 35° N W House [illegible]	In garden in front of house rather sheltered	644
7·95	2	2540	correct			
8·03	3	3790	+·001			
8·08	4	5060	+·001			
M 7·998	5	6310	+·003			
4·99	1	480	+·003	W School 22° N E Tree 33°	In garden in front of school on a short post	645
5·02	2	970	+·004			
5·00	3	1465	+·005			
5·00	4	1970	+·003			
M 5·001	5	2470	+·002			
8·01				Clear	On lawn near Rectory	646
8·00						
8·00						
8·01						
M 8·005						

EXAMINATION OF

Reference number	Date of examination	COUNTY Station *OWNER* *Observer*	Construction of gauge	Maker's name	Time of reading	Height of gauge	
						Above ground	Above sea level
	1875					ft in	feet
647	Dec 21	CAMBRIDGESHIRE The Observatory Cambridge *THE OBSERVATORY* *Mr Todd*	III	Casella	8 a m	1 0	85
	1876						
648	Mar 16	WESTMORELAND Kirkby Stephen *T MASON ESQ* *T Mason Esq*	XII	Casella	9 a m	1 0	574
649	Mar 16	WESTMORELAND Appleby *DR ARMSTRONG* *Dr Armstrong*	III	Anon	9 a m	1 0	442
650	Mar 17	YORKSHIRE Mickleton *G J SYMONS ESQ* *Mr Wade*		Casella	9 a m	1 0	775
651	Mar 17	DURHAM Gainford *A ATKINSON ESQ* *A Atkinson Esq*	XII	Casella	9 a m	1 0	250
652	Mar 17	YORKSHIRE Barningham Park *A SUSSEX MILLBANK ESQ*	V	Anon		1 1	650
653	Mar 17	YORKSHIRE Rokeby Rectory *REV H CLARKE* *Rev H Clarke*		Casella	9 a m	1 0	575
654	Mar 18	DURHAM Wolsingham *MR A MITCHELL* *Mr A Mitchell*	III	Anon	9 a m	1 0	464
655	Mar 20	NORTHUMBERLAND Allenheads *W B BEAUMONT ESQ* *Mr Kidd*	X.	Negretti & Zambra	9 a m	0 6	1350

RAIN-GAUGES (*continued*)

Diameters (that marked M = mean)	Equivalents of water		Error at scale point specified in previous column	Azimuth and angular elevation of objects above mouth of rain gauge	Remarks on position &c.	Reference number
	Scale point	Grains				
in	in		in			
4·98	1	500	– ·001	E Tree 30°	Gauge in garden of the Observatory fair position	647
5·02	2	980	+ ·002	S L 30°		
5·01	3	1480	+ ·001	S W Trees 25°		
4·99	4	1950	+ ·006	W Apple Tree 30°		
M 5·000	5	2450	+ ·006			
5·02	1	480	+ ·003	E Wall 30°	On edge of path in garden no better position available	648
5·00	2	950	+ ·008	N Tree 62°		
5·00	3	1460	+ ·006	S W 28°		
5·00	4	1960	+ ·005			
M 5·005						
8·08	1	1250	+ ·002	Clear	Gauge in garden E of house It appears to have been made by Mr Marshall of Kendal the receptacle being broken a new gauge was supplied	649
7·92	2	2550	+ ·001			
8·00	3	3780	+ ·002			
8·01	4	5120	– ·003			
M 8·002	5	6300	+ ·004			
7·95	1	1250	+ ·001	Quite clear	In small enclosed paddock near the middle of the village	650
8·02	2	2540	– ·001			
7·98	3	3770	+ ·002			
8·00	4	5050	+ ·001			
M 7·988	5	6320	+ ·001			
4·98	1	500	– ·001	E Building 38°	Mr Atkinson has recently started a new verified 5 in Snowdon pattern rain gauge 3 feet N of the above	651
5·01	2	1000	– ·002			
5·00	3	1460	+ ·005			
5·00	4	1950	+ ·006			
M 4·998	5	2470	+ ·001			
5·03	1	480	+ ·003	Quite clear	On lawn S S W of house	652
5·00	2	950	+ ·008			
4·98	3	1450	+ ·008			
5·00	4	1980	+ ·001			
M 5·002	5	2440	+ ·008			
8·00	1	1270	correct	Clear	In Rectory garden near corner of lawn	653
8·00	2	2540	correct			
8·00	3	3780	+ ·002			
8·00	4	5080	correct			
M 8·000	5	6350	correct			
4·98	1	475	+ ·004	Nothing over 20°	In garden N of house fairly open	654
5·03	2	970	+ ·005			
5·00	3	1470	+ ·004			
5·01	4	1970	+ ·003			
M 5·005	5	2490	– ·001			
7·98	1·18	1530	– ·001	S W Chimneys of house 35°	In small yard at rear of mining offices	655
8·07	2·44	3140	– ·003	S Wall, 20°		
7·99	5	6410	– ·005			
7·98						
M 8·005						

TABLES OF MONTHLY RAIN-

ENGLAND

	Division I —Middlesex								Div II —S E Counties			
	Middlesex								Surrey			
Height of Rain gauge above	Camden Square		Upper Clapton		Hampstead Squire's Mount		Muswell Hill		Dunsfold Godalming		Weybridge Heath	
Ground Sea level	0 ft 6 in 111 ft		1 ft 1 in 98 ft		1 ft 0 in 388 ft		0 ft 9 in 310 ft		2 ft 6 in 164 ft		0 ft 6 in 150 ft	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
	in	in	in	in	in	in	in	in	in	in	in	in
January	1 18	3 22	1 14	2 74	1 34	3 21	1 46	3 30	1 60	3 77	1 19	3 76
February	91	1 06	82	84	1 10	1 03	1 16	1 09	2 03	1 33	1 52	1 28
March	39	69	52	57	62	77	67	79	41	83	49	55
April	1 26	1 53	1 21	1 38	1 33	1 50	1 43	1 40	2 15	98	1 69	1 65
May	1 14	1 61	1 36	1 68	1 08	1 62	71	2 33	93	98	1 11	1 31
June	2 05	2 40	1 88	2 90	2 11	2 27	2 42	2 89	2 96	2 54	3 54	2 74
July	82	4 63	2 47	4 77	1 11	4 67	88	5 20	2 22	4 11	1 33	4 53
August	1 32	1 79	1 24	83	1 77	98	1 46	1 51	1 71	1 35	1 42	84
September	2 62	2 86	2 63	2 67	3 02	2 36	3 23	2 87	3 47	1 45	3 01	1 64
October	3 34	4 35	3 21	3 94	3 64	3 94	3 60	4 07	4 38	4 79	4 13	4 39
November	2 21	3 36	1 97	3 21	2 24	3 03	2 11	3 61	3 90	3 70	2 62	3 38
December	1 58	94	1 53	82	1 65	1 05	2 09	1 14	1 92	68	1 65	1 00
Totals	18 82	28 44	19 98	26 35	21 01	26 43	21 22	30 20	27 68	26 51	23 70	27 07

	Division II —South Eastern Counties (*continued*)											
	Kent (*continued*)						Sussex					
Height of Rain gauge above	River Head Sevenoaks		Acol Margate		Sidcup Foot's Cray		Brighton Lewes Road		Chichester Shopwyke		Bleak House, Hastings	
Ground Sea-level	0 ft 6 in 300 ft		1 ft 0 in 60 ft		0 ft 8 in 231 ft		3 ft 8 in 90 ft		1 ft 2 in 61 ft		1 ft. 1 in 77 ft.	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
	in	in	in	in	in	in	in	in	in	in	in	in
January	1 96	5 17	86	2 57	97	2 79	2 52	4 34	2 32	4 29	2 24	4 03
February	2 24	1 34	79	81	1 39	82	1 57	2 00	1 71	1 74	85	93
March	72	87	78	68	43	48	71	89	54	95	75	84
April	2 57	1 24	1 41	1 33	1 50	1 17	1 93	1 28	1 83	84	2 50	1 24
May	60	1 35	94	1 78	63	1 16	41	1 40	34	1 20	81	92
June	3 91	3 27	1 43	1 49	2 70	2 71	1 88	3 50	2 26	3 55	1 24	2 12
July	3 07	4 83	63	4 09	80	4 92	2 02	3 33	2 66	2 73	56	2 22
August	2 21	1 44	1 17	1 62	2 10	1 85	2 24	1 55	2 26	1 11	1 61	2 41
September	3 71	1 84	2 85	1 80	2 74	2 24	3 95	2 10	2 90	2 52	3 42	3 29
October	5 78	4 81	2 75	2 59	4 11	4 11	4 42	4 52	4 78	5 97	4 07	4 47
November	2 87	5 39	1 41	5 38	2 46	3 31	2 63	5 75	2 80	5 25	2 00	6 11
December	3 60	1 81	2 45	1 33	1 28	96	2 91	1 15	2 73	98	2 62	1 49
Totals	33 24	33 36	17 47	25 47	21 11	26 52	27 19	31 81	27 13	31 13	22 67	30 07

FALL IN THE BRITISH ISLES.

ENGLAND

Division II.—South Eastern Counties (continued)

Surrey (continued)								Kent					
Guildford Guildown		Kew Observatory		Kennington Road		Canterbury Bridge Street		Hythe		Linton Maidstone		Falconhurst Edenbridge	
0 ft 11 in 220 ft		1 ft [illegible] in 1[illegible] ft		5 ft 0 in 1[illegible] ft		1 ft 6 in 5[illegible] ft		0 ft [illegible] 1[illegible] ft		0 ft [illegible] in [illegible] ft		1 ft 0 in 400 ft	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in		in					in	in	in
1 23	3 01	98	3 00	70	2 84	1 56	3 68	2 28	4 42	1 27	3 62	1 47	3 80
1 87	1 59	1 16	93	82	79	1 29	86	1 08	1 31	1 31	93	2 30	1 13
47	0 92	44	62	8	60	98	62	1 3	82	83	92	77	88
1 81	1 23	1 26	1 70	1 10	} 2 67	2 20	1 22	3 51	82	1 91	1 38	2 46	1 31
59	1 13	60	1 39	1 07		1 06	1 05	93	1 72	1 1	1 38	57	1 20
2 97	2 60	2 52	2 63	2 62	2 18	1 72	2 15	2 58	2 16	2 63	2 30	2 55	2 93
1 24	4 76	1 16	4 77	97	4 21	89	5 90	2 34	4 31	72	5 60	2 44	4 51
1 74	1 17	1 29	65	58	1 03	1 96	1 67	3 7	2 51	2 07	1 38	2 41	1 86
2 69	1 36	2 93	2 02	1 58	1 96	2 63	2 13	5 15	3 04	3 02	2 20	3 05	1 86
4 29	4 63	3 55	3 81	3 42	3 82	3 26	3 55	3 50	4 86	3 59	3 85	5 21	5 20
2 44	4 10	2 31	2 94	2 25	2 65	2 38	6 02	2 6	8 82	1 98	4 39	2 69	4 13
1 54	1 56	1 42	93	1 38	73	2 36	1 80	3 21	3 24	2 95	2 30	2 54	1 54
22 88	28 05	19 62	25 39	17 37	23 48	22 29	30 65	32 28	38 03	23 49	30 25	28 46	30 35

Division II.—South Eastern Counties (continued)

Sussex (continued)												Hampshire	
Dale Park Arundel		Eastbourne		Uckfield Observatory		Chilgrove Chichester		Balcombe Place Cuckfield		Petworth Rectory		St Lawrence Isle of Wight	
3 ft 5 in 310 ft		4 ft 0 in 160 ft		6 ft 0 149 ft		0 ft [illegible] in 284 ft		1 ft 8 in [illegible]00 ft		[illegible] ft 0 in 100 ft		1 ft 0 in. 75 ft.	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in	in	in	in	in	in	in	in	in	in.
2 25	3 81	2 58	4 22	2 22	3 88	2 56	4 75	2 05	3 57	2 43	4 50	2 14	5·06
2 26	1 90	1 27	1 28	1 90	1 15	2 33	2 41	1 98	2 01	3 08	1 98	1 35	2 83
50	1 40	71	88	69	72	61	1 50	1 00	85	53	1 25	76	77
2 34	1 15	2 72	1 48	2 29	87	2 80	1 39	2 38	94	2 83	1 27	2 34	1 44
28	1 20	80	91	59	1 28	40	1 22	42	1 08	2 06	2 32	62	93
2 66	2 30	1 21	2 78	2 10	3 74	3 09	3 23	2 22	3 48	3 07	3 18	2 26	2 94
3 55	3 65	1 08	2 91	58	3 40	1 43	4 39	2 27	4 54	1 66	3 98	56	3 15
2 10	1 30	1 54	2 22	1 97	1 45	2 51	1 66	2 38	1 61	2 70	1 45	1 45	1 57
4 90	3 61	3 73	3 28	3 15	1 80	2 74	2 61	3 61	1 84	3 55	2 06	3 63	1·95
4 61	5 30	4 66	5 05	4 18	4 74	4 93	5 59	3 82	5 44	5 78	5 82	4 63	5 61
2 67	4 91	2 15	6 01	2 66	4 82	2 82	5 28	3 48	4 99	3 56	4 64	3 17	5·6
1 60	1 25	2 23	1 78	2 32	1 18	2 79	1 35	2 17	1 03	3 47	1 69	2 68	9
29 72	31 78	24 68	32 80	24 65	29 02	29 01	35 38	27 78	31 38	34 72	34 14	25 59	31 95

ENGLAND

DIVISION II.—SOUTH EASTERN COUNTIES (continued)

HAMPSHIRE (continued)

Height of Rain gauge above	Ryde Isle of Wight		Osborne Isle of Wight		Otterbourne Winchester		Cadland Southampton		Selborne		Liss Petersfield	
Ground	7 ft 0 in		0 ft 8 in		1 ft 3 in		4 ft [illegible]		4 ft 0 in		7 ft 7 in	
Sea level	20 ft		172 ft		11 ft		2 ft		400 ft		250 ft	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
	in	in	in	in	in	in	in	in	in	in	in	in
January	1 62	4 28	1 82	4 30	1 86	4 58	2 29	5 08	2 36	5 10	2 89	5 04
February	1 88	2 79	2 18	2 74	1 98	2 55	2 64	2 97	3 42	2 20	2 23	1 20
March	22	93	46	69	47	91	58	75	77	1 40	75	1 09
April	2 52	1 28	2 70	1 07	2 47	1 22	3 07	1 46	2 93	1 74	3 63	96
May	49	94	61	1 21	36	1 98	98	2 13	42	1 95	21	1 46
June	1 69	2 31	1 63	1 97	1 83	4 31	1 98	3 21	2 63	3 60	1 92	4 15
July	1 91	3 52	75	3 23	99	4 16	1 70	3 92	1 03	6 46	81	5 10
August	2 8[illegible]	98	2 46	1 05	2 62	2 76	2 99	2 12	3 07	1 32	2 61	1 01
September	3 07	1 78	2 96	1 43	4 50	1 34	3 75	1 67	2 76	1 87	3 31	2 58
October	4 61	5 84	4 67	5 11	4 52	4 66	5 43	6 57	6 28	5 83	5 48	5 78
November	4 26	5 66	3 32	4 48	3 10	4 57	3 79	4 67	4 02	4 73	3 60	4 61
December	3 28	1 25	2 92	1 20	1 99	59	3 41	1 24	3 32	1 61	3 12	1 60
Totals	28 44	31 46	26 48	28 48	26 69	33 63	32 61	35 79	33 01	37 71	30 56	34 58

DIVISION III.—SOUTH MIDLAND COUNTIES (continued)

	BUCKINGHAMSHIRE		NORTHAMPTON				BEDFORD		CAMBRIDGE			
Height of Rain gauge above	High Wycombe		Althorpe House		Wellingborough		Cardington		Wisbeach		Stretham Ely	
Ground	0 ft 9 in		3 ft 10 in		0 ft [illegible] in		0 ft 0 in		0 ft 6 in		4 ft 9 in	
Sea level	[illegible]25 ft		310 ft				106 ft		10 ft			
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
	in	in	in	in	in	in	in	in	in	in	in	in
January	1 87	3 69	1 78	2 71	1 90	3 08	1 60	2 30	1 28	2 05	1 20	1 51
February	1 5[illegible]	1 00	1 83	1 05	1 70	1 44	1 25	1 00	93	1 21	48	77
March	66	77	78	80	88	92	70	50	1 11	44	75	22
April	1 75	1 07	1 13	1 87	1 15	2 14	1 25	1 74	1 14	85	98	1 05
May	1 43	1 62	95	1 70	1 51	1 63	1 50	2 00	1 53	1 61	63	1 44
June	1 28	3 07	53	4 10	71	2 28	1 10	4 66	1 63	3 28	1 41	2 21
July	1 73	5 41	83	8 00	82	5 91	1 16	6 50	1 31	7 14	50	5 59
August	1 57	82	2 16	1 19	1 94	1 59	1 37	2 50	2 06	2 39	1 53	2 26
September	3 48	1 75	3 73	2 85	3 68	2 79	3 20	2 36	2 78	2 22	2 41	2 39
October	3 25	4 81	2 96	7 49	2 99	4 73	1 70	4 00	1 44	2 71	2 10	2 92
November	2 44	3 51	2 56	4 16	2 12	4 40	2 10	3 75	2 21	4 10	1 51	4 23
December	2 00	87	1 33	96	2 07	1 47	1 70	1 20	2 03	1 69	1 20	63
Totals	23 05	28 39	20 57	36 88	21 47	32 38	18 63	32 51	19 45	29 69	14 70	25 22

ENGLAND

Division II —South-Eastern Counties (*continued*)				Division III —South Midland Counties									
Hampshire (*continued*)		Berkshire		Hertfordshire						Oxfordshire			
Aldershot		Long Wittenham		Berkhampstead		Royston		Hitchin		Radcliffe Observatory		Banbury	
0 ft 6 in 325 ft		1 ft 0 in 170 ft		1 ft 0 in 370 ft		0 ft 6 in 2[illegible] ft		1 ft 0 in 238 ft		0 ft 11 in 208 ft		7 ft 0 in 350 ft	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in	in	in	in	in	in	in	in	in	in
1 71	4 53	2 28	4 10	2 16	3 29	1 40	2 09	1 52	2 15	2 30	3 57	2 15	2 69
2 12	3 05	1 74	1 60	2 19	1 18	1 22	75	1 41	1 05	1 68	1 45	1 95	96
46	64	61	77	82	75	86	47	72	63	61	1 09	85	80
2 21	1 64	1 05	1 21	2 28	1 47	1 37	1 42	1 84	1 58	1 28	1 46	1 43	2 13
77	1 65	1 49	2 01	1 83	2 46	1 01	1 90	62	2 00	1 56	1 76	1 76	2 12
2 21	2 55	67	2 32	1 22	3 73	1 26	2 88	1 35	2 75	68	2 96	50	2 97
1 30	5 88	1 09	4 46	93	5 14	53	4 52	2 05	6 24	49	4 70	2 14	5 39
2 24	1 54	1 61	1 35	1 69	1 56	1 17	1 57	1 11	1 32	1 82	1 80	2 09	1 12
2 72	1 70	3 42	2 54	4 02	2 62	2 80	2 66	3 01	2 07	3 34	2 03	3 21	2 38
4 34	6 06	3 11	7 39	3 16	6 54	2 19	3 06	2 59	3 94	3 13	7 53	3 13	7 80
2 04	4 29	2 17	3 79	2 37	4 02	2 01	3 65	1 96	4 16	2 53	3 76	2 52	4 84
2 36	1 79	2 34	96	2 57	1 11	1 97	79	2 07	1 04	1 82	87	1 81	1 12
24 48	35 32	21 58	32 50	25 24	33 87	17 79	26 36	20 25	28 93	21 24	32 98	23 54	34 32

Division IV —Eastern Counties

Essex										Suffolk			
The Hemnalls Epping		Dorward's Hall Witham		Dunmow		Bocking Braintree		Ashdon Rectory		Grundisburgh		Culford, Bury St. Edmund's	
0 ft 8 in 346 ft		1 ft 6 in 20 ft		0 ft 0 in 250 ft		1 ft 0 in		1 ft 0 in 300 ft		3 ft 9 in		1 ft 6 in	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in	in	in	in	in	in	in	in	in	in
47	3 26	1 12	2 19	1 15	2 48	1 20	2 28	1 46	3 00	99	1 91	1 24	2 34
1 14	92	75	75	86	72	1 04	98	92	85	1 02	96	75	1 21
72	61	88	46	74	42	1 29	51	60	40	69	53	1 07	42
1 52	1 48	1 28	1 40	1 12	1 18	1 44	1 32	1 08	84	1 36	1 13	69	1 05
66	2 41	81	2 51	90	1 53	82	1 93	1 66	1 99	1 51	2 36	49	2 15
2 86	3 02	1 93	1 79	2 43	4 25	2 16	3 16	1 40	2 33	1 31	2 68	1 64	2 83
2 95	5 86	1 37	4 48	01	3 90	1 14	4 99	1 58	5 09	1 28	4 33	76	5 29
1 07	1 08	96	56	1 57	85	1 53	81	1 20	82	1 14	0 61	1 18	88
3 00	3 33	1 82	2 64	2 04	2 52	2 61	2 94	2 47	3 56	2 95	2 21	3 14	2 67
3 97	3 63	2 87	2 44	3 24	3 10	2 43	3 40	2 69	3 54	1 69	4 48	2 08	3 24
1 91	4 09	1 90	3 56	2 25	3 59	2 19	4 04	2 00	4 26	2 34	4 88	2 62	5 26
2 33	1 37	2 33	47	1 31	89	2 03	1 27	1 77	89	1 79	1 43	2 17	1 84
22 60	31 06	18 02	23 25	19 62	25 43	19 88	27 63	18 83	27 57	18 07	27 51	17 83	29 18

ENGLAND

	Division IV.—Eastern Counties (*continued*)								Division V.—South-Western Counties.			
	Norfolk								Wilts			
	Geldeston, Beccles		Cossey, Norwich		Swaffham		Holkham.		Wilton, Salisbury		Marlborough, Mildenhall	
Height of Rain-gauge above Ground	1 ft 0 in		1 ft 0 in		1 ft 0 in		0 ft 0 in		0 ft. 5 in		1 ft 0 in	
Sea-level	40 ft				160 ft		39 ft		180 ft		467 ft.	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875.
	in	in	in	in	in	in	in	in	in	in	in	in
January	89	1 70	1 07	2 23	1 41	2 48	1 25	1 70	2 80	4 71	3 13	4 55
February	97	97	1 08	1 29	91	1 33	1 35	1 68	3 00	2 56	2 49	2 14
March	93	52	85	56	1 21	57	1 05	77	60	1 54	1 09	1 35
April	1 03	75	1·04	69	1 12	88	1 25	85	2 10	1 54	1 62	1 57
May	1 23	1 35	1 94	1 49	81	1 79	1 08	95	80	1 69	59	2 44
June	2 91	1 75	2 06	1 57	1 96	1 54	1 30	2 02	1 20	2 98	89	2 70
July	1 52	4 13	1 11	5 08	1 07	5 96	60	8 31	90	4 06	1 27	5 33
August	1 73	0 75	1 35	69	2 06	1 62	1 65	99	2 50	2 29	2 46	2 18
September	3 68	2 00	3 19	2 42	2 81	2 41	2 02	1 80	4 30	2 01	3 92	3 50
October	1 30	3 69	1 65	3 56	1 66	3 00	2 25	2 30	5 10	6 03	4 37	7 22
November	2 35	5 29	3 16	5 81	2 80	5 25	2 70	5 63	3 00	4 71	2 89	4 08
December	2 46	1 78	2 45	2 39	2 87	1 89	3 10	2·75	3 40	1 21	2 38	1 16
Totals	21 00	24 68	20 95	27 78	20 69	28 72	19 60	29 75	29 70	35 33	27 10	38 22

	Division V.—South-Western Counties (*continued*).											
	Devonshire (*continued*)											
	Landscore, Teignmouth.		Clevelands, Lyme Regis		Cove, Tiverton		Castle Hill, S Molton		Clawton, Holsworthy		Barnstaple	
Height of Rain-gauge above Ground	0 ft 6 in		1 ft 11 in		0 ft 4 in		3 ft 1 in		1 ft 1 in		1 ft 0 in.	
Sea-level ..	200 ft.		463 ft		450 ft ?		300 ft		400 ft ?		31 ft	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874.	1875.
	in	in	in	in	in	in	in	in	in	in	in.	in.
January	3·37	5 63	2 81	6 11	4 53	6 32	5 38	8 20	3·89	8·04	4·06	5·79
February . .	3 35	2 12	3 03	1 85	4 01	2 13	2 32	2 04	3 15	1 76	2 81	1·79
March .	1 87	1 48	·63	98	1 32	1 75	2 12	1 68	1 95	1·65	2·07	1·23
April	2·52	1·61	2 34	1 53	1 55	2 47	1 98	2 13	2·47	1 95	1 89	2·16
May	1 19	2 86	1 04	2 82	1 08	3 06	36	3 74	99	2 05	·70	2·61
June ..	1 73	3·61	3·03	2 86	1 20	3 99	·92	3 61	1 97	3·57	1 48	4·01
July ..	1 18	4 38	1 27	4·61	2 40	3·91	4 00	2 78	3·04	2 76	2 77	3·35
August .	2 02	2 51	1 99	3 21	4·59	3 53	5 87	2 55	4 88	2 56	5 65	3·30
September	5 70	4·43	6 80	2 89	7·56	3 63	8 12	5 37	8·19	5 79	5 93	5 53
October .	8 49	9·11	5 66	8 25	5 30	9 64	6 49	7·85	3 31	6 68	4·44	6 40
November	4·41	5 99	3·46	6·45	3·51	6·71	3 06	8 21	2 94	7 48	3·06	7·15
December ..	5·77	1 09	4 39	·98	6·90	1 50	10 08	2·25	5·74	2 19	7 10	2·02
Totals......	41·60	44·82	36 45	42·54	43·95	48·64	50 70	50·41	42·52	46·48	41·96	45·34

ENGLAND

Division V —South-Western Counties (continued)

Wilts (continued)		Dorset						Devonshire					
Chippenham Tytherton		Longthorns		Weymouth Osmington Lodge		Shaftesbury		Saltram		Fore Street Hill Kingsbridge		Holne Vic Dartmoor	
1 ft 2 in 157 ft		0 ft 4 in 340 ft		1 ft 0 in 225 ft		1 ft 3 in 722 ft		0 ft 3 in 96 ft		1 ft 0 in 63 ft		1 ft 0 in 650 ft	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in	in	in	in	in	in	in	in	in	in
2 81	4 16	3 33	5 67	2 94	5 56	2 94	4 44	7 89	10 37	5 08	7 64	9 81	14 19
1 88	2 02	3 41	2 67	2 42	2 99	2 39	2 74	3 98	1 50	4 15	1 79	7 41	2 70
92	78	46	1 22	66	1 17	63	86	1 36	1 43	1 24	1 17	1 71	2 70
1 30	1 75	2 09	1 55	2 26	1 23	2 95	1 87	2 56	3 80	2 27	1 81	4 99	2 87
34	2 49	45	1 72	61	2 23	88	2 51	89	90	1 29	2 45	1 38	4 77
1 09	2 58	1 57	2 75	1 50	1 89	2 22	2 78	2 35	3 65	1 89	3 85	9 10	5 64
73	5 37	1 41	5 29	98	3 89	1 71	5 91	1 75	5 39	1 55	5 00	1 79	6 24
2 69	1 32	2 78	1 68	2 80	2 79	3 19	1 04	2 25	3 44	2 65	2 14	6 19	4 21
4 93	3 34	3 93	1 03	3 74	2 36	6 15	2 53	9 15	6 79	4 42	7 80	8 85	7 31
3 55	7 36	5 84	8 32	5 81	8 15	5 69	6 90	7 36	8 35	6 87	6 80	10 83	12 04
2 14	3 98	3 53	5 40	3 38	5 67	2 56	5 10	4 70	6 02	4 29	6 89	53	10 55
2 27	0 87	3 94	1 30	4 16	1 35	2 61	1 41	5 54	2 10	7 46	2 22	10 33	3 37
24 65	36 02	32 74	38 60	31 26	39 28	33 92	38 09	49 78	53 74	43 16	49 56	72 92	76 59

Division V —South-Western Counties (continued)

Cornwall													
Crowan Camborne		Penzance		Tehidy Park Redruth		Truro Royal Institution		Trevarna St Austell		Bodmin Castle Street		Altarnum	
0 ft 6 in 519 ft		3 ft 0 in 94 ft		0 ft 6 in 100 ft		40 ft 0 in 56 ft		0 ft 6 in 300 ft		2 ft 4 in 338 ft		1 ft 0 in 570 ft	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in	in	in	in	in	in	in	in	in	in
5 62	8 64	5 15	9 54	4 53	6 90	4 80	7 98	5 34	9 55	5 70	9 93	7 52	12 75
3 86	2 57	3 70	3 24	4 05	2 15	4 35	2 45	4 21	1 74	5 22	1 59	5 04	2 44
1 31	1 30	1 58	1 20	4 25	1 35	1 17	1 39	1 82	1 59	2 03	1 78	2 78	1 56
2 34	2 39	2 68	2 54	1 80	2 00	1 96	1 94	2 76	2 49	2 34	2 04	3 63	3 05
80	3 11	68	2 88	1 08	2 30	1 34	2 35	52	3 20	94	2 92	96	3 67
1 80	3 58	2 24	3 33	2 00	3 10	1 84	2 56	1 92	4 08	2 05	3 33	2 26	4 33
1 53	3 70	1 38	3 40	1 50	2 80	1 60	2 70	1 30	3 57	1 99	3 20	2 24	5 50
4 08	2 50	3 07	1 99	3 90	3 45	3 71	2 78	4 31	2 30	4 56	2 66	6 55	2 98
7 15	4 55	5 25	4 95	6 30	4 50	5 90	5 53	7 54	7 48	[illegible]	7 40	7 76	7 02
6 11	7 47	5 61	8 77	5 15	6 10	4 59	7 17	4 78	9 85	3 33	8 49	8 09	7 32
4 59	5 09	5 21	6 61	4 20	6 79	4 43	5 80	5 41	8 27	4 73	6 83	5 28	9 76
8 14	3 38	9 92	3 12	7 70	3 60	8 04	2 21	9 43	2 64	6 72	2 73	8 99	3 57
47 33	48 28	46 47	51 57	46 46	45 04	43 73	44 86	49 34	56 76	48 16	52 90	61 10	63 95

ENGLAND

	Division V —South Western Counties (*continued*)								Division VI —West Midland Counties			
	Somerset								Gloucester			
Height of Rain gauge above	Fullands School Taunton		Ilchester		Sherborne Reservoir E. Harptree		Batheaston Reservoir		Clifton		The Firs Cirencester	
Ground	1 ft 4 in		2 ft 6 in		1 ft 0 in		2 ft 0 in		0 ft 6 in		0 ft 8 in	
Sea level			30 ft		338 ft		226 ft		192 ft		352 ft	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
	in	in	in	in	in	in	in	in	in	in	in	in
January	2 10	3 02	2 52	4 87	6 05	8 46	3 10	4 85	3 93	5 14	3 28	5 30
February	2 14	2 45	2 79	2 06	4 59	3 19	2 30	2 00	2 40	2 25	2 39	2 56
March	56	49	1 01	68	2 54	1 96	1 25	1 10	2 14	1 46	1 08	1 07
April	2 09	1 69	1 79	78	3 06	2 71	1 60	1 80	1 99	2 09	1 59	1 98
May	1 02	2 80	85	2 07	1 11	4 16	45	2 35	66	2 87	1 01	2 39
June	1 06	2 47	1 08	2 46	1 74	5 92	1 60	3 35	1 06	3 52	1 84	3 42
July	90	4 54	1 12	4 88	1 00	6 84	95	6 25	1 56	5 99	1 09	5 56
August	1 66	2 09	2 84	2 17	5 30	1 94	3 50	1 30	4 64	1 79	3 18	1 21
September	4 65	2 65	4 26	1 92	7 94	4 88	6 15	4 25	7 07	4 60	5 45	2 80
October	4 77	6 59	4 12	4 56	6 22	8 37	4 15	6 35	3 82	6 98	3 81	7 82
November	2 21	4 49	2 52	2 87	4 17	6 85	2 55	4 45	2 36	6 08	2 81	5 04
December	2 60	48	3 29	16	6 22	2 06	2 40	80	3 62	1 28	2 78	1 64
Totals	25 76	33 76	28 19	29 48	50 03	57 34	30 00	38 85	35 25	44 05	30 31	40 79

	Division VI —West Midland Counties (*continued*)								Division VII —North Midland Counties			
	Worcester (*continued*)				Warwick				Leicester			
Height of Rain gauge above	Worcester		Orleton Tenbury		Arden House Henley in Arden		Birmingham		Fleckney Market Harboro		Thornton Reservoir	
Ground	0 ft 8 in		0 ft 9 in		2 ft 2 in		0 ft 8 in		0 ft 8 in		2 ft 8 in	
Sea-level	112 ft		200 ft		400 ft		340 ft		411 ft		420 ft	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
	in	in	in	in	in	in	in	in	in	in	in	in
January	2 29	3 37	2 51	3 16	2 64	3 17	1 96	4 58	2 28	3 03	1 61	3 19
February	2 80	1 56	3 06	2 14	2 26	1 17	2 69	1 68	51	1 64	1 65	91
March	79	64	1 04	98	1 14	52	1 19	80	70	1 09	79	52
April	1 86	99	1 59	1 14	1 45	1 12	1 98	1 09	1 03	1 01	1 14	91
May	2 27	2 51	2 05	2 56	2 25	2 52	3 24	2 10	1 27	2 14	1 38	1 33
June	75	2 39	1 15	2 32	81	2 61	87	3 20	1 23	6 11	71	5 55
July	1 11	6 69	80	6 17	1 53	6 83	1 25	8 85	88	6 09	82	6 64
August	1 91	1 96	2 64	4 08	1 85	1 54	2 18	2 02	2 67	2 57	2 51	1 84
September	3 57	2 97	3 67	3 26	3 73	3 48	3 57	3 30	2 92	2 40	2 73	2 91
October	2 62	6 68	2 11	5 94	1 97	7 26	3 58	7 36	1 88	5 51	2 24	6 18
November	2 69	4 81	3 29	4 04	2 83	4 71	2 77	3 46	2 48	3 98	2 69	3 95
December	2 07	1 30	2 83	1 63	2 32	1 51	2 60	92	1 81	1 02	2 01	1 28
Totals	24 73	35 87	26 74	37 42	24 78	36 44	27 88	39 36	19 66	36 59	20 28	35 21

ENGLAND

DIVISION VI —WEST MIDLAND COUNTIES (*continued*)

GLOUCESTER (*continued*)		HEREFORD		SHROPSHIRE				STAFFORD		WORCESTER			
Saul Lodge Frampton on Severn		Stretton Rectory Hereford		Haughton Hall Shifnal		Hengoed Oswestry		Barlaston Stoke		Northwick Park		West Malvern	
3 ft 6 in 42 ft		1 ft 0 1 8 ft		3 ft 6 3 3 ft		6 ft 0 470 ft		0 ft 6 in 00 ft		1 ft 6 in		1 ft 6 in 850 ft	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in	in		in	in	in	in	in	in	in
3 28	4 68	2 80	3 76	1 81	2 46	2 88	4 66	2 92	3 69	3 12	3 70	2 72	3 73
2 19	1 83	2 53	2 23	2 41	1 56	2 95	1 56	2 81	1 11	2 24	1 61	2 98	1 43
1 02	1 29	78	1 18	88	82	1 69	1 37	1 59	81	60	79	68	1 06
1 82	2 80	1 54	86	1 17	66	2 01	1 29	1 49	51	1 81	2 30	2 18	98
54	1 93	1 41	2 53	1 98	1 15	2 55	3 05	1 44	1 82	2 73	2 53	1 52	3 24
75	3 14	1 02	2 52	77	2 63	75	3 75	81	3 18	35	2 05	1 11	2 74
97	4 43	85	4 80	1 17	5 59	1 88	4 68	1 63	6 75	2 10	6 32	1 82	7 49
2 19	96	2 43	1 88	2 62	3 56	3 29	3 33	3 66	2 69	2 47	1 31	2 26	2 03
4 78	3 04	4 09	4 31	2 88	4 14	3 23	4 60	3 36	3 79	3 76	2 70	3 75	3 68
2 46	5 22	2 93	6 03	1 65	5 32	2 86	5 83	2 83	4 65	3 96	8 71	3 06	8 18
2 01	5 31	2 69	4 99	3 3	3 56	4 82	3 85	4 43	3 56	3 13	5 22	2 70	4 96
2 32	1 68	2 67	1 82	2 43	1 03	3 62	1 62	3 27	1 29	2 95	81	2 00	·91
24 33	36 31	25 80	36 91	23 50	32 48	32 53	39 99	30 30	33 85	29 22	38 05	26 78	40 43

DIVISION VII —NORTH MIDLAND COUNTIES (*continued*)

LEICESTER (*continued*)		LINCOLN											
Belvoir Castle		Lincoln		Market Rasen		Gainsborough		Brigg		Grimsby		New Holland	
1 ft 0 in 237 ft.		3 ft 6 in 26 ft		3 ft 6 in 111 ft		76 ft		3 ft 6 in 16 ft		15 ft 0 in 42 ft		3 ft 6 in 18 ft	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in	in	in	in	in	in	in	in	in	in
1 58	1 96	1 24	3 08	98	1 27	78	1 59	1 06	1 32	86	1 61	1·08	1 63
1 59	1 44	1 53	1 19	1 35	60	1 41	1 12	1 09	37	1 16	83	1 16	1·05
1 05	57	74	57	71	1 57	30	68	75	71	85	43	72	65
1 13	97	1 36	54	44	92	1 48	72	1 74	52	79	34	94	29
97	1 01	1 68	85	82	1 09	1 46	91	1 19	93	1 04	98	94	1 75
45	2 44	1 17	2 64	1 05	2 78	91	1 96	66	2 95	46	2 62	49	2 02
90	5 42	46	3 66	2 29	4 91	1 46	4 07	1 00	4 02	1 13	4 02	1 12	3 65
1 94	1 92	1 64	2 00	2 43	1 30	2 19	2 49	1 72	1 80	1 80	1 79	1 94	3 91
2 14	2 24	1 65	1 63	2 42	65	1 97	2 12	1 57	2 58	1 69	1 97	1 55	2 06
1 60	4 95	1 34	3 89	2 41	5 99	2 17	4 34	1 35	3 14	1 37	3 65	1 69	4 03
2 06	4 20	2 43	4 41	1 61	3 60	1 70	3 51	2 01	4 86	3 05	5 01	2 81	5 41
1·69	1 10	1 34	1 28	1 25	23	1 08	82	1 47	76	2 18	98	1 84	1 13
17 20	28 22	16 58	25 74	17 76	24 91	16 91	24 33	15 61	23 96	16 38	24 23	16 28	27 50

ENGLAND.

Division VII —North Midland Counties (*continued*)											Div. VIII.—N.-Western Counties.	
	Nottingham		Derby								Cheshire.	
Height of Rain-gauge above Ground Sea-level	Welbeck 4 ft 6 in 88 ft		Spondon, Derby 0 ft 7 in 262 ft		Chesterfield 3 ft 6 in 248 ft		Comb's Moss 3 ft 6 in 1669 ft		Chapel-en-le-Frith 3 ft 6 in 965 ft		Cholmondelly Castle, Nantwich 1 ft 6 in 42 ft	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
	in	in	in	in	in	in	in	in	in	in	in	in
January	1 48	2 62	1 98	3 25	2 89	3 64	5 61	3 91	4 24	4 90	2 44	2 60
February	1 74	1 23	1 62	1 47	1·75	87	3 24	97	2 28	1 25	2 95	1 65
March ...	·97	75	1·31	72	1 33	1 05	3 49	58	3 52	67	94	·80
April	2 12	92	1 22	79	2 32	85	2 09	1 13	2 67	1 37	1 61	52
May ...	1 49	1 59	1 08	2 01	·77	1 31	1 70	2 32	1 57	2 18	1 89	2 05
June	78	3 34	51	2 87	46	2 96	1 13	3 42	63	3 14	·40	2·93
July	1 84	3 86	1 14	6 29	1 20	4 54	1 86	6 01	2 66	3 90	1 87	5 34
August	2 05	3 81	2 23	3 31	2 55	4 72	4 65	3 96	6 13	2 83	3·20	3·05
September	2 02	2 82	2 67	3 97	2 15	3 11	3 44	5 32	3 21	4 69	3·02	4 75
October	3 03	5·01	1 79	5 10	3 25	5 77	4 04	7 65	4 92	6 02	2 91	5 18
November ..	2·82	4 32	2 67	3 78	4 15	4 37	4 23	4 77	5 18	4 74	3 96	3 63
December	1 87	1 21	2 01	1 21	1 85	1 60	1 42	1 51	2 43	1 96	3 07	1 06
Totals .	22 21	31 48	20 23	34 77	24 67	34 79	36 90	41 55	39 44	37 65	27 36	33 56

Division VIII.—North-Western Counties (*continued*).									Div. IX —Yorkshire.			
	Lancashire (*continued*)								York —West Riding			
Height of Rain-gauge above Ground Sea-level. ...	Stonyhurst 1 ft. 3 in. 376 ft		Caton, Lancaster 1 ft 0 in 117 ft		Holker, Cartmel 4 ft 8 in 155 ft		Coniston 1 ft 0 in 287 ft		Broomhall Park, Sheffield 2 ft 0 in 330 ft		Redmires, Sheffield 5 ft 0 in. 1100 ft.	
	1874	1875	1874	1875	1874.	1875	1874	1875	1874	1875	1874	1875.
	in.	in	in	in	in	in	in	in	in	in	in	in.
January .	5 26	5·13	4·72	5 20	4 61	6 67	10 89	13 41	1 51	2 84	2 81	4·58
February ..	1 78	1 40	1 77	93	2 34	1 37	5 33	3 63	1 57	1 25	1·70	1·38
March	6 45	1 25	3 77	1 03	3 08	1 08	5 75	2 66	1 74	0 80	2·77	1·31
April	1·81	1 59	1·59	1 29	0 98	1·35	2 67	2 78	1 52	·68	1 99	1·44
May	1 84	2·92	1 49	2 57	1 23	2 50	1 32	3 77	87	1 62	1 38	2·37
June .. .	2 05	4·47	1 12	4 24	1 62	3 99	1 34	5 35	71	3 59	1 33	4·52
July . .	3·04	5 69	2 42	4·03	2 15	2·52	4·41	3 18	72	4 06	2·09	5·30
August	7 21	3 76	6 70	3 83	7·16	3 54	12 07	4 73	2 64	4 98	4·07	5·29
September ..	5 56	5 88	4 75	4·19	5 01	6 06	7 64	9 38	1·72	3 49	2·68	4·51
October	6·90	3 78	6 38	3 24	8 59	5·29	13·99	7 72	3 15	6 35	4·31	7·25
November ...	5·35	5 81	5·26	5 12	4 61	6 35	8 70	9 06	3 27	4·52	4·78	6·31
December . .	3·95	2·58	4 08	2·73	3·71	2·46	5·03	5 77	2 81	1·42	2·30	1·76
Totals ...	51·20	44·26	44 05	38·40	45 09	43 17	79·14	71·44	22·23	35 60	32·21	45·78

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Division VIII —North Western Counties (continued)

Cheshire (continued)		Lancashire											
Macclesfield		Manchester		Waterhouses		Bolton le Moors		Rufford Ormskirk		Over Darwen		South Shore Blackpool	
3 ft 6 in 539 ft		2 ft 7 in 106 ft		3 ft 6 in 345 ft		3 ft 6 in 286 ft		0 ft 8 in 38 ft		1 ft 0 in 600 ft		1 ft 8 in 29 ft.	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in	in	in	in	in	in	in	in	in	in
2 60	2 66	3 53	3 57	4 99	4 27	4 86	5 60	2 80	3 79	5 82	6 16	2 88	3 55
2 17	58	1 59	74	1 99	98	1 88	1 08	1 61	85	2 75	1 20	1 90	1 00
1 65	55	3 37	82	4 10	48	4 66	87	2 96	76	6 51	1 57	1 45	58
1 80	60	1 00	90	1 29	1 26	1 46	1 11	1 15	71	2 31	1 68	1 08	65
2 38	1 46	1 39	2 07	1 90	1 80	1 96	2 39	1 42	2 02	1 95	2 77	1 20	1 40
68	2 06	1 00	3 56	1 29	3 78	1 63	5 01	1 09	3 19	1 90	4 22	25	3 85
2 95	4 78	1 77	4 60	1 69	4 42	3 46	5 67	2 65	6 37	3 67	5 80	1 72	6 30
4 06	1 44	4 34	5 00	4 39	2 87	6 77	3 00	4 12	2 62	7 76	3 51	4 00	2 20
4 52	2 72	3 86	4 74	4 60	5 04	4 20	5 92	3 27	4 59	5 09	5 52	3 25	4 65
2 70	3 81	3 76	4 45	4 24	4 34	5 97	6 13	5 19	4 82	7 42	5 68	5 40	4 55
4 40	2 59	4 85	4 22	4 42	4 17	7 38	5 57	4 53	3 55	6 11	4 58	4 25	3 80
1 81	1 18	3 64	82	3 07	1 53	4 44	1 59	3 06	1 32	3 68	2 32	2 35	1 40
31 72	24 43	34 10	35 49	37 97	34 94	48 67	43 94	33 85	34 59	54 97	45 01	29 73	33 93

Division IX —Yorkshire (continued)

York —West Riding (continued)

Tickhill		Penistone		Saddleworth		Ackworth Pontefract		Goole		Stanley Vic Wakefield		Ovenden Moor Halifax*	
1 ft. 0 in. 61 ft		3 ft 6 in 717 ft		0 ft 5 in 640 ft		1 ft 6 in 135 ft		3 ft. 4 in		1 ft 0 in 100 ft		0 ft 6 in. 1375 ft.	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in	in	in	in	in	in	in	in	in	in.
96	2 15	1 63	3 95	4 31	3 22	71	2 32	95	2 31	1 02	3 08	3 00	5 90
1 26	1 33	1 53	52	1 51	3 20	1 10	1 34	1 02	1 14	1 10	1 22	1 40	1 40
97	53	3 23	63	4 22	94	95	50	96	43	1 38	42	4 50	1 90
1·62	57	1 24	84	2 40	1 05	1 14	34	1 27	41	1 10	48	1 60	1 50
98	1 25	1 53	1 56	1 17	2 99	90	1 13	1 22	1 09	84	1 41	1 50	2 00
1 58	2 71	19	3 43	1 41	4 05	72	4 65	27	1 80	74	3 52	1 80	4 10
1 98	5 60	1 32	4 57	1 86	4 67	1 36	5 01	1 34	3 88	1 83	4 08	2 70	6·40
2 53	2 97	3 73	3 05	5 60	1 80	1 53	2 10	1 43	2 68	1 50	2 46	5 00	3 20
1 57	2 22	1 61	2 92	2 03	4 74	2 26	2 64	1 49	2 42	2 19	2 70	4 10	4 90
2 44	5·13	3 90	5 56	4 04	3 62	2 03	4 37	1 56	4 10	1 66	3 93	5 70	6 30
2·62	3 95	1 16	4 73	4 34	4 37	2 51	3 74	2 61	3 33	2 64	3 48	4 60	6·10
1 98	83	1 61	1 60	2 61	1 47	2 75	65	1 16	1 34	2 30	79	4 00	2 50
[illegible]	29·24	22 68	33 36	35 50	36 12	17·96	28 79	15 28	24 93	18 30	27 57	39 90	46·20

ENGLAND

DIVISION IX.—YORKSHIRE (continued).

Height of Rain-gauge above	YORK.—WEST RIDING (continued).						YORK.—EAST RIDING.					
	Fecup, Leeds		York		Harrogate		Arncliff		Beverley Road, Hull		Warter, Pocklington	
Ground	0 ft 9		0 ft [illegible]		0 ft [illegible] in		ft 9		3 ft 10 in		1 ft 10 in	
Sea-level	340 ft		[illegible] ft		[illegible] ft		[illegible] ft		11 ft		230 ft	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
	in		in		in	in		in			in	in
January	2·14	3·78	1·09	2·29	2·05	4·37	8·20	10·78	1·05	2·35	1·32	2·94
February	1·40	2·22	1·35	1·20	1·41	2·49	3·12	1·92	1·33	1·07	1·55	1·45
March	2·01	1·30	1·36	·55	2·64	1·66	6·6	2·25	1·18	·81	1·90	·97
April	1·44	·67	1·28	·44	1·32	·48	2·95	3·01	1·01	·47	1·82	·61
May	·72	1·38	1·96	1·61	1·66	1·20	2·52	4·45	1·56	1·35	2·18	1·71
June	·58	2·36	·99	2·10	·81	2·42	1·53	4·65	·57	1·85	·75	1·96
July	1·89	3·06	1·18	3·05	2·33	2·86	3·92	4·91	1·48	3·69	1·58	3·87
August	2·40	2·57	2·34	2·17	2·90	2·81	9·52	3·56	1·98	3·56	2·61	2·69
September	2·25	3·01	2·85	2·23	2·25	2·00	7·19	5·23	1·80	2·49	1·68	3·08
October	2·51	4·39	2·17	4·21	2·74	4·64	8·47	5·14	1·77	4·34	2·42	5·59
November	2·69	4·13	3·22	3·83	2·48	4·39	5·13	7·66	3·71	5·76	4·60	6·18
December	2·94	1·25	3·35	·89	3·79	1·35	5·71	4·79	2·75	1·13	3·92	1·67
Totals	22·97	30·12	23·14	24·57	26·38	30·67	64·87	58·35	20·19	28·87	26·33	32·72

DIVISION X.—NORTHERN COUNTIES (continued).

Height of Rain-gauge above	NORTHUMBERLAND.								CUMBERLAND.			
	Bywell		North Shields		Haltwhistle		Lilburn Tower		Bootle		Seathwaite	
Ground	0 ft 6 in		1 ft 0 in		0 ft 9 in		6 ft 0 in		1 ft 0 in		1 ft 0 in	
Sea-level	87 ft		126 ft		380 ft		800 ft		87 ft		422 ft	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
	in	in	in	in	in	in	in	in	in	in	in	in
January	2·65	2·58	1·50	2·33	3·48	4·58	1·33	1·86	3·88	5·60	20·82	22·88
February	2·28	1·83	·95	1·21	1·77	1·59	1·50	3·18	3·09	1·24	10·50	3·43
March	1·47	·98	1·04	·51	3·82	·81	1·84	1·21	2·33	1·22	14·24	5·66
April	1·61	1·09	·72	·76	2·75	1·23	·89	1·97	1·51	1·56	4·72	4·53
May	2·85	1·21	2·30	·72	1·95	2·48	2·09	1·11	1·03	2·50	2·82	7·80
June	1·01	2·11	1·00	1·57	1·68	2·29	·91	2·76	1·06	4·52	3·02	10·96
July	1·72	4·21	1·47	5·38	2·48	4·41	2·00	1·62	2·09	3·54	7·20	5·75
August	2·60	4·19	1·55	3·41	5·02	1·97	3·16	1·54	7·72	4·17	18·60	7·87
September	2·63	2·92	1·76	2·59	3·96	3·79	1·25	2·26	5·38	5·89	16·06	14·43
October	2·18	5·44	1·65	3·26	4·77	2·86	1·80	3·81	5·91	6·01	30·18	10·08
November	4·28	6·03	3·30	5·81	4·73	5·52	4·02	4·64	4·67	4·67	13·29	12·10
December	5·06	2·06	3·79	1·44	3·13	2·55	3·44	2·89	4·17	2·35	7·34	15·95
Totals	30·34	34·65	21·03	28·99	39·54	34·08	24·23	28·85	42·84	43·27	148·79	[illegible]

ENGLAND.

Division IX.—Yorkshire (*continued*).												Division X.—Northern Counties.			
York.—E. R. (*continued*).		York.—North Riding										Durham			
Ganton Hall, Scarborough		Malton		Whitby.		Northallerton		Middlesborough				Durham Observatory		Wolsingham	
1 ft. 0 in. 250 ft.		1 ft. 0 in. 75 ft.		2 ft. 0 in. 184 ft.		1 ft. 3 in. 133 ft.		1 ft. 6 in. 21 ft.				4 ft. 8 in. 340 ft.		1 ft. 0 in. 464 ft.	
1874	1875	1874	1875.	1874	1875	1874	1875	1874	1875			1874	1875	1874	1875
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.			in.	in.	in.	in.
1·22	2·36	1·60	2·72	1·19	1·86	1·85	2·25	1·09	1·74			2·28	4·25	2·80	4·49
1·72	·88	1·36	·82	1·27	·75	1·57	1·29	·76	·66			2·06	1·74	1·61	1·98
1·86	·83	1·50	·58	1·58	·56	·47	·30	1·13	·33			1·54	·70	2·01	·71
1·21	·60	1·26	·40	·73	·95	·97	·99	·60	·73			1·82	1·02	1·86	1·12
2·79	1·10	2·06	1·59	3·50	·88	1·98	1·24	2·22	1·05			3·21	1·14	2·54	1·44
0·39	3·07	·93	2·78	·84	2·90	·78	2·63	1·36	2·67			1·42	2·61	1·51	2·15
1·30	4·59	1·29	3·94	2·51	4·74	1·60	4·21	1·13	3·24			1·85	4·31	·79	4·59
2·06	2·26	2·34	3·45	2·38	2·25	2·36	1·75	1·66	2·25			2·77	2·59	2·53	2·77
1·99	2·48	2·40	1·89	2·14	1·63	2·70	2·07	2·59	1·71			2·54	3·24	2·80	2·96
1·78	5·39	2·00	3·90	1·38	4·61	2·67	2·46	·95	2·77			2·40	6·69	2·54	5·60
3·58	6·57	3·27	5·23	2·93	6·60	·96	4·00	2·08	5·66			4·63	7·13	3·48	6·46
4·19	1·74	3·18	1·19	3·46	1·62	4·01	1·07	2·75	1·47			6·53	1·84	5·12	2·51
24·09	31·87	23·19	28·49	23·91	29·35	21·92	24·26	18·32	24·28			33·05	37·26	29·59	36·78

Division X.—Northern Counties (*continued*).													
Cumberland (*continued*)						Westmoreland.							
Whinfell Hall, Cockermouth		Post Office, Keswick.		Scaleby Hall		Kendal.		Kirkby Stephen		Appleby		Great Strickland, Penrith.	
2 ft. 0 in. 265 ft.		1 ft. 0 in. 270 ft.		1 ft. 0 in. 112 feet.		1 ft. 6 in. 146 ft.		1 ft. 0 in. 574 ft.		1 ft. 0 in. 442 ft.		1 ft. 0 in. 650 ft.	
1874.	1875.	1874.	1875	1874.	1875	1874	1875	1874	1875	1874	1875	1874.	1875.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
6·39	6·36	6·94	8·51	4·00	4·23	6·76	8·44	5·63	6·41	4·35	5·28	5·02	6·24
4·55	1·43	4·91	1·25	2·55	·97	3·10	1·43	2·85	·91	2·77	·69	2·69	·62
3·97	1·60	4·57	2·02	2·50	·69	4·38	1·73	3·98	1·16	3·44	1·31	3·02	1·41
2·03	1·48	3·68	1·58	1·29	·96	1·96	1·69	3·13	1·29	2·72	·54	3·16	·80
1·06	3·10	1·17	3·32	1·58	1·70	1·05	2·63	2·07	1·73	1·52	1·61	1·86	2·04
1·26	4·35	1·47	4·24	1·70	2·78	1·21	5·28	1·14	3·04	·92	3·30	1·60	3·35
2·34	3·47	2·82	3·41	2·87	3·73	2·98	2·40	1·55	3·14	1·62	3·61	1·50	3·79
9·00	4·24	9·13	3·10	6·65	2·13	7·40	3·06	4·83	2·92	4·77	1·71	5·20	2·05
7·38	6·66	8·19	6·38	4·25	3·69	5·76	5·75	5·54	5·26	4·24	4·98	5·97	4·77
11·45	4·69	14·76	4·42	5·63	3·19	12·60	3·33	8·71	3·42	6·72	2·81	9·43	3·51
5·96	4·76	4·40	5·40	4·85	3·36	4·22	6·57	3·20	4·57	3·26	3·12	2·84	3·41
2·75	3·95	3·85	5·90	2·64	1·95	3·69	3·91	2·88	3·66	2·69	3·48	3·05	3·12
[illegible]·14	46·09	65·89	49·53	40·51	29·38	53·11	46·22	45·51	37·31	39·02	32·44	45·34	35·01

WALES.

Division XI —Monmouth, Wales, and the Islands.

	Monmouth				Glamorgan				Carmarthen		Pembroke	
Height of Rain-gauge above	Newport		Abergavenny		Swansea		Pentyrch, Cardiff		Carmarthen Gaol		Haverford-west.	
Ground ..	1 ft 0 in		1 ft 0 in		14 ft 9 in		1 ft 1 in		0 ft 6 in.		1 ft 0 in	
Sea-level	180 ft		220 ft		40 ft		100 ft		92 ft		95 ft.	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
	in	in	in	in	in	in	in	in	in.	in.	in	in
January	6 10	6 61	4 91	5·76	4 75	6 03	6 91	7 54	6 34	9·51	5 62	9·70
February ..	3 32	2 51	3 54	2 22	2 76	2 12	2 99	2 97	4 38	2 75	4 73	2 80
March	2 51	2·18	88	1 72	2 79	1 15	3 50	2 01	3 70	1·60	3 48	1 64
April .	2 20	2 80	2 15	2 09	1 19	1 41	1 89	3 08	3 34	2 98	2 34	2 77
May	·37	3 15	65	2 83	43	1 84	2 03	3 48	87	3 55	97	2 86
June . .	1 95	5 92	53	3 17	2 12	3 40	2 14	6 49	1 47	3·76	1 31	3 39
July . .	1 42	7 89	83	6 08	1 55	3 82	1 63	7 22	2 23	6 56	2 55	5 50
August	5 07	1 87	2 99	1 97	4 69	6 33	6 45	5 87	7 30	7 02	6 11	4 66
September	5 96	4 66	5 29	3 95	4 74	4 39	6 36	5 02	8 07	5 81	4 47	6 29
October	5 18	7 48	4 43	7 40	4 35	5 72	5 97	8 09	6 88	6 30	6 16	7 28
November .	2 99	7 96	2 90	6 93	2 71	7 20	3 36	8 88	3 08	7 47	5 32	7 61
December .	4 52	2 61	3 99	2 15	4 22	2 11	5 77	2 56	5 97	3 56	8 09	3 93
Totals	41·59	55 64	33 09	46 27	36 30	45 52	49 00	63 22	53 63	60·87	51 15	58·43

Division XI.—Monmouth, Wales, and the Islands (*continued*).

	Merioneth				Flint				Carnarvon			
Height of Rain-gauge above	Dolgelly, Brithdir.		Bala.		Maes-y-dre		Bryn Alyn		Beddgelert.		Cocksidia, Carnarvon.	
Ground ..	1 ft. 6 in.		1 ft 0 in		5 ft 0 in		1 ft 2 in		3 ft 0 in.		1 ft 1 in.	
Sea-level	465 ft.		544 ft		400 ft.		483 ft		264 ft		120 ft.	
	1874	1875	1874	1875	1874	1875	1874.	1875	1874	1875	1874.	1875
	in	in	in	in	in	in	in	in	in.	in.	in	in.
January . ..	7·79	9 69	5 11	7 36	1 87	1 72	2 15	3 27	14 32	13·45	3 79	4·08
February ..	6 83	3 45	3 36	1 93	1 18	·61	2 08	2 08	5 13	7 40	3 31	2·17
March . .	3 71	2 62	5 30	1·81	1·23	25	1 34	·79	9 84	5 07	1 67	1·27
April	3 72	3·43	2 63	1 97	·95	60	1 25	1 11	6 44	3 71	1·90	1 37
May	1·97	3·48	2 02	2 75	2 15	1 77	2·30	1 88	4 24	5 34	2 21	2·39
June .. .	1 83	4 03	1 04	4 01	·52	1·81	·48	2 10	3·27	8·07	·90	3·37
July	4·24	4 38	3 28	4 19	2 38	2 51	2 73	5·25	7 15	4·54	3·11	3·31
August	10 11	2·28	5 93	2 82	2 53	2 07	3 47	3 08	14 99	6 63	4·50	2·16
September	9 78	7 77	5 33	4 61	1 71	2 80	2 89	4 28	9 55	10·22	4 55	4·97
October ..	8 98	7 88	8·23	5·25	2 86	3·74	3·69	4 02	19·74	13·25	4·69	5·52
November ...	10·18	9·92	5 04	5 50	3 13	3 16	4·09	4 96	17·12	13 99	4·52	3·63
December .	7 28	5 53	6·21	3·82	1 82	·77	3·61	1 24	9·75	8 47	4·29	2·45
Totals . .	76·42	64·46	53·48	46·02	22·33	21·81	30·08	34 06	121·58	100·14	39·44	[illegible]

WALES.

Division XI.—Monmouth, Wales, and the Islands (*continued*).

Pembroke (*continued*)		Brecknock		Montgomery		Cardigan				Radnor			
Ivy Tower, Tenby		Brecknock		Llanidloes		Lampeter		Goginan		Nantgwilt		Heyhope Rectory.	
1 ft. 0 in. 180 ft.		2 ft. 0 in. 437 ft.		2 ft. 0 in. 550 ft.		5 ft. 0 in. 420 ft.		2 ft. 6 in. 290 ft.		1 ft. 0 in. 707 ft.		1 ft. 0 in. 690 ft.	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874.	1875.	1874	1875.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
5·03	8·76	5·43	6·67	5·10	5·11	5·01	5·91	4·52	5·69	7·56	10·16	3·86	5·24
4·35	2·46	4·11	2·30	4·03	2·91	4·39	1·56	2·72	2·50	5·52	1·75	2·81	2·82
2·52	1·56	2·52	1·99	4·11	1·94	2·79	1·79	3·76	1·23	3·46	1·66	2·15	1·90
2·16	2·79	2·80	2·56	1·92	3·88	2·11	1·87	1·91	1·71	3·14	2·75	1·19	2·08
·79	2·97	·79	2·80	1·70	3·59	1·71	2·10	1·59	2·36	1·78	3·64	·87	2·76
1·64	3·84	2·24	3·56	1·39	3·32	1·56	2·55	1·28	3·69	2·23	6·35	·42	3·66
1·86	7·02	1·25	4·17	2·64	4·10	2·50	5·21	3·11	4·47	2·42	7·26	1·66	5·89
6·16	5·14	4·10	2·98	6·23	2·41	4·36	4·27	7·65	4·17	8·61	4·63	5·44	3·59
5·17	6·67	4·68	5·41	5·39	4·00	6·04	5·25	4·80	5·61	6·81	6·56	3·68	4·34
5·25	6·96	5·65	6·72	5·38	8·18	5·07	6·68	4·04	5·54	7·33	8·89	4·58	7·24
5·10	8·35	2·61	8·44	4·76	6·15	4·29	7·85	5·18	5·21	7·11	8·12	4·05	5·05
6·59	3·21	2·32	1·88	6·35	2·30	5·44	1·72	5·54	2·18	7·12	3·54	5·03	2·60
46·62	59·73	38·50	49·48	49·00	47·89	45·27	46·76	46·10	44·36	63·09	65·31	35·74	47·17

Division XI.—Monmouth, Wales, and the Islands (*continued*).

Carnarvon (*continued*).				Isle of Man				Guernsey		Sark.		Jersey.	
Llanfairfechan.		Llandudno.		Douglas		Point of Ayre.		Guernsey		Sark.		Millbrook.	
0 ft. 8 in. 150 ft.		0 ft. 8 in. 99 ft.		1 ft. 1 in. 79 ft.		. . . .		12 ft. 0 in. 204 ft.		1 ft. 0 in. 840 ft.		1 ft. 0 in. 60 ft.	
1874.	1875	1874	1875	1874	1875	1874	1875.	1874	1875	1874	1875.	1874.	1875.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
3·73	4·50	2·88	3·03	5·15	6·65	2·35	3·83	1·94	5·00	1·62	4·07	2·48	5·31
3·14	2·80	1·46	2·14	2·39	2·55	1·21	·64	2·41	3·27	1·91	2·75	2·04	2·96
2·66	1·67	2·12	·89	1·76	1·26	1·10	1·12	·85	·66	1·11	·45	1·38	·65
1·91	1·26	1·40	·94	1·79	·91	1·11	·91	3·62	1·14	2·89	·94	1·99	·85
3·35	2·02	2·68	1·46	1·39	2·64	·77	1·84	·94	1·30	·50	1·28	·65	·80
·27	2·44	·35	1·81	·48	2·93	·15	1·78	1·13	2·59	·89	2·28	·78	2·06
2·04	4·20	1·97	3·47	2·61	4·56	1·64	1·67	1·85	2·84	1·64	3·15	1·74	2·51
3·18	2·22	2·81	2·00	5·89	2·15	3·96	1·11	1·67	1·23	1·62	1·78	1·86	1·13
3·27	4·91	2·53	4·65	2·38	3·39	1·44	2·46	2·68	2·94	1·94	2·46	2·68	2·70
5·04	5·00	3·42	5·30	4·82	4·56	3·42	4·68	6·82	6·15	5·21	6·25	5·17	7·62
5·67	4·37	5·64	4·25	7·00	5·63	3·95	4·46	3·57	6·13	2·86	6·50	3·20	5·79
4·75	2·02	4·43	1·41	3·80	1·90	3·12	1·48	7·90	2·39	5·39	1·99	8·11	1·53
39·01	37·41	31·69	31·35	39·46	39·13	24·22	25·98	35·38	35·64	27·58	33·90	32·08	33·91

SCOTLAND.

Division XII.—Southern Counties.

	Wigtown		Kirkcudbright.						Dumfries.			
Height of Rain-gauge above	Balfern.		Little Ross		Carsphairn		Cargen		Drumlanrig		Wanlockhead	
Ground	0 ft 11 in		3 ft 3 in		3 ft 10 in		0 ft 4 in				0 ft 5 in.	
Sea-level	75 ft		130 ft		574 ft		80 ft		191 ft		1330 ft.	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874.	1875.
	in	in.	in	in	in	in	in	in	in	in	in	in
January	4 24	7 72	2 71	3 38	6 92	15 13	5·70	8 42	5 90	11 10	7 51	14 14
February	2 26	1 29	1 85	1 19	3 46	2 08	2 30	1 21	3 00	2·10	4 62	2 08
March	3 21	1 20	1 79	83	3 86	3 14	2 74	1 60	3 90	2 80	3 88	3 56
April	1 90	1 10	1 24	59	4 50	1 52	3 98	1 50	3 80	2 10	4 53	2 36
May	95	2 83	73	1 85	1·11	3 42	1 17	1 84	1 20	2 90	99	3 36
June	1 39	3 23	83	2 54	1 68	3 80	1 35	4 58	1 45	5 90	1 71	5 63
July	3 14	2 40	1 74	1 86	3 20	2 50	1 84	2 45	3 90	2 70	3 15	2 83
August	6 27	4 32	3 93	3 03	6 38	3 70	7 07	2 30	6 80	3 10	7 96	2 85
September	3 24	7 04	2 23	4 72	5 95	7 70	6·00	5 47	6 60	7 60	7 04	9 52
October	8 03	5 72	4 49	6 12	12 63	5 41	10 72	5 22	11 10	4 80	12 47	5·25
November	5 70	4 91	4 29	6 55	9 21	8 61	5 50	4 44	6 30	6 40	4 71	7 19
December	4 38	2 67	2 11	3 77	2 90	6 27	2 69	4 11	2 28	4 90	2 59	6 96
Totals	44 71	44 43	27 94	36 43	61 80	63 28	51 06	43 14	56 23	56 40	61 16	65 73

Division XIV.—South-Western Counties

	Lanark						Ayr.				Renfrew.	
Height of Rain-gauge above	Newmains, Douglas		Auchinraith, Hamilton.		Glasgow Observatory		Hole House, Patna.		Mansfield, Largs.		Newton Mearns.	
Ground	0 ft 4 in		4 ft 0 in		0 ft. 1 in		1 ft 0 in.		0 ft 6 in.		1 ft. 0 in.	
Sea-level	783 ft.		150 ft		180 ft		446 ft		30 ft		350 ft.	
	1874	1875.	1874	1875	1874	1875	1874	1875	1874	1875.	1874.	1875
	in	in	in	in	in	in	in	in	in	in.	in	in
January	4 56	5 06	2 84	4 55	4 27	6 67	4 83	4·60	5 30	10 80	6 44	7·10
February	2 59	2 31	60	·90	1·03	1 74	2 28	1 44	1 40	2 10	1 84	2·25
March	2 93	1 33	2 00	1 37	3 45	2·13	3 66	1 45	1 20	1 80	5·20	3 03
April	2 43	1 60	1 40	86	1 88	1 68	1 58	1 69	2 70	2 00	3 59	1 51
May	1 04	1·43	1 90	83	2·50	1 55	1 43	2 44	1 80	2 90	2 75	3 00
June	1 13	3·56	1 32	2 20	90	3 57	1 71	2 64	1 00	3 40	1 30	2 86
July	2 04	2 78	3 20	1 71	4 03	1·89	3 10	2 14	2 60	2 10	2 66	1·83
August	6 06	2 07	5·48	2·25	4 74	2 98	5 08	2·83	5 00	4 90	4 83	3 47
September	4 83	5 65	3·30	3 60	4 41	5 45	4 59	4·94	5·10	8 90	6 24	5·97
October	7·16	4 74	4·90	4·30	8 02	5 86	7 64	4·39	8 30	7 60	11 17	5 07
November	4 36	3 87	2·90	3 76	4 26	5·19	5·77	4 82	5 60	5 50	4·88	5·94
December	2 70	4·48	1·38	3 06	2 87	5 58	2 79	3 21	2·50	4·50	4·50	7·07
Totals	41·83	38·88	31·02	29·39	42·36	44 29	44 46	36 59	42 50	56·50	55·40	49·10

SCOTLAND.

Division XIII.—South-Eastern Counties.

Roxburgh		Selkirk		Peebles		Berwick		Haddington		Edinburgh			
Silverbut Hall, Hawick		Bothwickbrae		North Esk Reservoir, Penicuick		Thirlestane		East Linton		Glencorse		Charlotte Sq., Edinburgh.	
4 ft 0 in. 512 ft		0 ft 2 in 800 ft.		0 ft 6 in 1150 ft		0 ft 3 in 558 ft		0 ft 3 in 90 ft		0 ft 6 in 787 ft		0 ft 6 in. 230 ft	
1874	1875	1874.	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in.	in	in	in	in	in	in	in	in	in
2 11	4 09	4 00	7·60	3 45	4 45	2 50	3 80	1 20	1 91	3 45	5 70	1 74	2·74
2 16	1 07	2 40	1 50	85	1 30	1 50	1 90	60	1 39	1 20	1 00	70	1 17
1 88	1 21	3 30	1·90	2 35	1 75	1 50	80	1 00	64	2 20	1 60	1·73	·90
1 95	97	2 50	1 10	2 15	1 40	1 15	·45	68	·40	2 75	1 15	90	67
1 72	1 36	1 60	1 80	1 60	1 55	95	1 30	1 37	48	2 00	1 60	1·50	·75
·78	2 76	1 80	2 70	1 00	2 70	1 00	2 30	1 47	2 73	1 50	2 75	1 60	2·00
2·20	2 54	2 40	3 20	2 70	3 30	2 00	2 60	4 52	2 65	2 55	3 85	3 34	3·26
5 03	2 38	7 20	2 20	6 50	2 55	5 20	90	4·54	96	6 60	2 50	4 87	1 13
3 33	3 48	4 00	5 90	3 30	4 60	2 00	3 70	2 16	2 64	3 20	4 50	1 75	2 67
4 83	2 54	8 90	3 40	4 80	3 60	3 10	4 45	2 26	3 93	5 15	3 40	2 42	2·34
4 65	3 71	5 40	4 60	4 45	5 70	4 30	5 00	4 69	5 05	3 70	5 75	3 11	4·92
2 81	2 64	4 10	5 00	1 90	3 40	3·13	2 30	2·98	1 15	1 55	2 90	2 10	1 81
33 45	28 75	47 60	40 90	35 05	36 30	28 33	29 50	27 47	23 93	35 85	36 70	25 76	24·36

Div. XIV. (*continued*).		Division XV.—West Midland Counties.											
Renfrew (*continued*)		Dumbarton				Stirling		Bute		Argyll.			
Glenbrae, Greenock		Balloch Castle		Arddarroch, Loch Long		Arnott Hill, Falkirk		Pladda.		Castle Toward		Calton Mór.	
0 ft. 9 in. 574 ft		0 ft. 4 in 91 ft.		0 ft 10 in. 80 ft		1 ft 6 in 135 ft		3 ft 3 in 55 ft		4 ft 0 in 65 ft.		4 ft. 0 in. 65 ft.	
1874.	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874.	1875.
in	in	in	in	in	in	in	in	in	in	in	in	in.	in.
9·60	10 60	6·24	9 07	11·18	12 86	4·52	5 84	3 77	4·65	4·87	8·13	6 91	6·97
2 80	2 60	2 18	1 46	2 95	2·62	1·15	1·21	1·25	1 24	1 54	1 50	2·89	2·15
6·10	2·60	5·55	2 18	9 78	3 51	3 03	1 39	3 45	1 54	4 37	2 27	6·04	2·34
3·70	2 50	2 28	2 24	6 23	3·66	1 81	1·20	2 37	1 24	2 94	1 15	3 90	2 84
2·40	4·10	2 64	3 74	2 78	5 30	2·30	2 20	1 95	2 18	2 63	3 05	2·09	3·54
1·90	3 50	1 60	3 84	1·84	5 21	1 20	2 78	93	1·99	1 21	2 94	1·65	3·59
3·50	2·50	3 57	2 02	4 70	2·26	3·95	2·19	2 37	1 58	2 76	2 35	4·21	2·65
6·20	4·80	6 33	5·15	6 78	6 73	5 28	2 12	4·96	3·06	4 49	4 55	5·58	6·[illegible]
8·80	5·30	6 48	5 90	11 22	6 03	2 31	1·98	4 08	3 01	6 91	4 69	8·23	3·72
12·20	8·60	9 00	7·35	14 03	10·43	4 39	4·02	7 17	6 22	9 47	6 72	8 76	7·15
6·00	6·30	6·10	5·57	9·79	7 36	4·51	4·92	5·50	5 47	6 12	4·17	6 27	6·26
2·30	7·10	3 10	5·93	2 94	9 28	2·50	4 55	2 83	3 90	2·28	4·50	2·77	4·70
65·00	60·50	55·07	54·45	84·22	75·25	36·95	34·40	40 63	36·08	49·59	46·01	59·30	52·20

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Division XV.—West Midland Counties (*continued*).

Argyll (*continued*)

Height of Rain-gauge above	Inverary Castle		Airds, Appin		Corran, Loch Fil		Ardnamurchan		Devaar, Campbeltown		Skipness Castle	
Ground ..	0 ft 2 in		0 ft 3 in		0 ft. 4 in.		3 ft 6 in		3 ft. 4 in.		1 ft 6 in	
Sea-level	30 ft.		38 ft		14 ft.		82 ft		75 ft		20 ft.	
	1874.	1875.	1874	1875	1874	1875	1874	1875.	1874	1875	1874	1875.
	in	in	in	in	in	in	in	in	in	in	in	in.
January .	10·00	6·00	7·20	6·40	12·33	4·95	6·04	6·37	4·02	6·04	5·40	4·90
February	3·00	2·00	3·10	2·30	3·20	1·45	2·80	1·72	1·41	1·45	3·40	1·90
March	9·00	2·50	7·20	2·60	10·35	2·20	4·83	1·93	2·91	2·03	5·20	2·50
April .	4·00	2·00	4·10	2·80	5·10	3·10	3·50	2·20	3·16	·50	3·30	·50
May .	2·00	4·00	2·60	4·80	2·20	4·20	1·49	3·48	1·03	2·29	1·40	3·00
June	1·00	5·00	2·90	4·30	2·30	2·27	1·97	2·58	·52	2·52	1·70	3·10
July	5·00	1·50	5·10	2·70	3·25	2·64	3·17	1·97	2·77	1·53	2·90	2·70
August ...	6·00	6·00	7·70	8·60	3·57	12·61	5·24	6·17	4·68	3·25	5·00	3·60
September	11·00	7·00	9·20	3·40	7·10	3·90	9·64	2·52	4·25	3·42	7·30	5·70
October	13·00	5·00	10·80	4·40	8·80	5·60	7·85	4·19	6·99	9·67	7·60	5·80
November .	9·00	4·00	4·30	5·50	3·05	5·30	4·61	4·65	8·32	5·74	6·20	6·60
December ..	4·00	11·00	2·30	6·00	1·90	9·65	2·30	3·70	3·65	3·39	4·70	5·00
Totals . .	77·00	56·00	66·50	53·80	63·15	57·87	53·44	41·48	43·71	41·83	54·10	45·30

Division XVI.—East Midland Counties (*continued*).

Perth (*continued*).

Height of Rain-gauge above	Ledard.		Loch Katrine.		Auchterarder House.		Dunkeld.		Bonskeid, Pitlochrie.		Scone Palace.	
Ground .	. .		0 ft 6 in.		2 ft 3 in.		1 ft. 0 in		....		2 ft. 6 in.	
Sea-level .	150 ft.		830 ft.		162 ft.		225 ft.		.. . .		80 ft.	
	1874	1875	1874.	1875.	1874.	1875	1874.	1875	1874	1875	1874.	1875.
	in	in	in.	in	in	in.	in.	in	in.	in	in.	in.
January ...	4·30	12·30	8·00	14·60	3·97	6·61	4·00	5·66	5·82	4·54	2·50	4·97
February	1·90	1·40	3·50	2·40	·68	1·26	1·52	1·51	1·29	1·17	·70	1·00
March	4·80	3·70	8·50	3·70	1·96	1·83	3·21	1·72	1·33	1·54	1·60	1·67
April	1·90	1·90	4·20	2·40	2·30	·63	3·05	1·28	3·29	1·07	1·14	1·66
May	3·80	4·70	2·70	5·70	2·11	1·54	2·31	1·30	·59	2·10	1·51	3·00
June	2·00	5·30	2·80	5·40	·70	2·00	1·25	3·40	1·84	2·77	·61	1·14
July	5·20	2·30	7·10	2·20	4·22	2·81	5·01	2·02	3·52	2·59	2·32	1·98
August .	6·90	6·80	5·20	5·70	3·39	2·14	3·91	3·57	6·88	2·21	6·25	2·39
September ...	8·90	8·00	11·60	7·20	2·97	2·79	4·19	5·26	4·00	3·75	1·97	3·43
October	10·00	8·60	13·60	10·10	5·63	4·86	5·30	5·58	5·50	7·46	2·45	5·67
November .	4·30	6·10	7·90	8·00	4·72	5·10	3·28	4·70	2·40	3·45	4·15	3·60
December ..	1·60	7·60	2·70	10·20	1·48	5·11	3·06	5·19	2·10	2·70	1·10	2·46
Totals	55·60	68·70	77·80	77·60	34·13	36·68	40·09	41·19	38·56	35·35	26·30	32·97

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Div XV —West Midland Counties (*continued*)								Division XVI —East Midland Counties					
Argyll (*continued*)								Kinross		Fife		Perth	
Rhinns of Islay		Ballab s Islay		Lismore		Hynish		Loch Leven Sluice		Nookton		Kippenross	
3 ft. 0 in 74 ft		1 ft 0 in 67 ft		3 ft 4 in 37 ft				0 ft 6 in 360 ft		0 ft 6 in 80 ft		0 ft 4 in 150 ft	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in	in	in	in	in	in	in	in	in	in
2·55	4·76	4·44	6·53	5·16	5·15	7·34	8·91	3·40	5·50	2·39	4·99	3·70	8·00
2·33	1·75	2·92	2·10	1·84	1·56	4·87	3·47	1·10	1·90	1·05	1·86	·60	·90
2·04	1·47	3·65	2·00	4·48	1·73	8·47	1·49	2·40	1·90	2·10	1·58	3·10	1·70
2·35	·63	3·30	1·37	3·25	1·16	3·53	1·54	2·10	1·00	1·46	·76	1·85	·50
1·33	1·61	1·29	2·58	2·57	2·49	3·30	3·07	2·10	1·30	1·74	1·19	1·00	1·50
·84	1·93	1·06	2·63	1·96	2·60	1·66	3·58	·40	2·20	·63	2·41	1·15	2·70
2·63	·64	3·13	1·42	4·65	1·47	3·69	1·89	2·70	2·10	1·99	2·91	2·10	1·70
3·02	3·58	4·48	5·46	3·44	4·63	4·28	4·48	4·80	2·20	3·97	1·51	4·50	2·10
4·67	3·50	6·41	4·40	6·23	1·59	12·25	3·39	4·00	3·90	2·48	3·05	3·60	3·60
4·68	6·12	7·39	7·47	8·06	1·82	6·76	7·22	5·20	5·70	3·32	4·03	6·30	5·30
5·00	4·14	7·86	6·03	3·51	2·64	9·78	4·72	3·20	5·30	2·38	4·51	4·20	5·00
2·92	2·63	4·30	4·17	1·01	3·08	2·93	3·63	2·00	4·60	2·02	2·57	·80	5·20
34·36	32·76	50·23	46·16	46·16	29·92	68·86	47·39	33·40	37·60	25·53	31·37	32·90	38·20

Division XVI —East Midland Counties (*continued*)								Division XVII —North Eastern Counties					
Perth (*continued*)		Forfar						Kincardine		Aberdeen			
Dalnaspidal		Dundee Necropolis		Arbroath		Montroseness		The Burn Brechin		Braemar		Aberdeen, Rose Street	
1 ft 6 in. 1450 ft		0 ft 5 in 167 ft		2 ft 0 in 60 ft				0 ft 6 in 2 0 ft		0 ft [illegible] in 1114 ft		0 ft. 5 in 95 ft	
1874.	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875.
in	in	in	in	in	in	in	in	in	in	in	in	in	in.
8·00	9·07	2·10	4·15	2·22	3·92	2·05	3·20	2·40	4·90	2·91	4·30	1·31	3·36
2·75	2·02	·75	1·50	1·10	1·30	1·15	2·00	1·30	2·20	2·54	·81	1·54	1·60
7·84	3·37	·95	1·80	1·02	1·77	1·02	1·90	1·60	2·70	2·32	1·34	1·89	2·41
4·48	2·04	·80	·65	·81	·66	·60	1·20	2·20	1·20	2·42	1·35	·97	1·39
3·16	4·02	2·75	·85	2·43	·84	1·80	1·20	2·20	1·40	1·20	1·64	1·34	1·90
2·62	3·10	·75	3·55	·64	3·40	·05	2·45	·50	3·40	2·45	2·00	1·03	3·15
6·05	3·69	2·70	2·35	1·70	2·43	2·05	2·50	2·60	2·80	4·41	3·53	2·61	3·78
7·15	5·64	5·55	1·45	4·97	1·56	5·05	1·55	5·50	3·90	6·79	3·20	6·31	[illegible]
7·79	6·51	1·90	3·40	2·10	3·41	1·85	4·40	1·80	5·50	3·34	4·12	2·33	[illegible]
11·78	8·29	2·30	5·90	1·99	4·17	2·20	3·65	3·20	7·00	5·72	5·54	2·44	[illegible]
4·90	4·71	2·60	4·70	2·19	4·84	2·30	3·90	3·10	5·10	2·56	4·07	3·60	[illegible]
2·70	10·63	2·20	1·55	1·75	1·81	1·00	1·90	2·40	3·10	1·42	4·39	3·02	[illegible]
69·22	63·09	25·35	31·85	22·92	30·11	21·12	29·85	28·80	43·20	38·08	36·20	28·38	34·67

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Division XVII —North Eastern Counties (*continued*)									Div XVIII —North-Western Counties			
	Aberdeen (*continued*)				Banff		Elgin		Ross and Cromarty			
Height of Rain gauge above	Leochel Cushnie		Tillydesk Ellon		Gordon Castle		Grantown		Inverinate House Loch Alsh		Gairloch	
Ground Sea-level	3 ft 0 882 ft		0 ft 4 343 ft		1 ft 6 in 70 ft		1 ft 1 in 712 ft.		3 ft 0 in 150 ft		0 ft. 0 in 13 ft	
	1874	187	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
	in	in	in	in	in	in	in	in	in	in	in	in
January	1 15	1 99	1 56	3 29	1 47	2 49	2 16	1 94	11 37	7 70	5 61	2 61
February	1 35	1 59	1 91	1 94	1 31	1 48	1 04	1 15	2 85	1 60	2 06	1 82
March	2 16	1 63	2 77	1 80	1 78	1 46	2 82	2 07	12 45	3 90	5 05	2 33
April	88	1 24	87	1 59	74	1 34	1 10	1 10	6 40	3 70	2 81	2 37
May	1 96	1 76	1 49	2 23	2 06	1 72	2 39	1 45	2 70	8 95	3 25	3 56
June	1 88	2 87	93	2 91	1 62	1 99	1 23	3 06	5 55	5 05	2 75	2 97
July	2 47	4 47	2 29	3 99	1 58	6 16	3 30	5 44	5 40	4 10	3 83	4 69
August	9 64	4 70	6 83	2 46	5 37	2 16	6 55	3 29	7 20	10 75	4 26	5 35
September	2 59	3 55	1 94	5 30	2 44	4 24	2 74	3 80	13 60	5 60	7 41	2 92
October	3 38	7 34	2 94	4 85	3 21	2 38	3 11	1 88	14 80	5 08	7 05	2 59
November	3 85	4 96	4 51	4 75	3 74	3 71	2 51	3 43	6 50	5 80	3 02	3 81
December	3 54	1 96	3 95	1 91	2 85	1 94	1 95	3 04	3 65	8 95	2 28	3 57
Totals	34 85	38 06	31 99	37 02	28 17	31 07	30 90	31 65	92 47	71 18	49 38	38 59

Division XVIII —North Western Counties (*continued*)							Division XIX —Northern Counties					
	Inverness (*continued*)						Sutherland					
Height of Rain-gauge above	Island Glass Harris		Corrimony Glen Urquhart		Laggan		Dunrobin		Scourie.		Cape Wrath	
Ground Sea level	3 ft 4 in. 50 ft		0 ft 8 in 537 ft		0 ft 9 in 821 ft		3 ft 0 in 9 ft		0 ft 4 in 26 ft.		3 ft 6 in 353 ft	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874.	1875
	in	in	in	in	in	in	in	in	in	in	in	in
January	7 25	6 08	5 60	5 10	1 04	4 94	4 00	3 72	5 30	4 40	6 51	4 81
February	2 04	1 73	1 80	1 50	2 13	2 19	50	1 50	1 00	2 20	1 25	1 50
March	5 68	1 42	4 10	2 40	6 02	3 46	3 30	1 06	4 30	1 10	3 96	70
April	3 48	1 67	4 70	70	6 61	2 31	1 45	1 53	2 90	2 20	1 93	1 62
May	2 23	3 12	1 80	2 50	5 34	5 16	1 60	1 38	2 90	3 20	74	2 26
June	2 76	2 99	1 40	2 00	5 78	4 62	1 40	2 28	2 90	1 10	2 70	1 52
July	2 94	91	3 70	2 70	4 34	3 09	1 10	2 66	3 30	2 50	2 07	2 30
August	5 39	6 03	5 50	2 90	6 57	6 83	5 00	2 26	4 30	5 10	3 86	1 33
September	5 55	1 72	5 90	2 80	9 68	4 11	2 60	2 02	4 80	2 30	3 80	1 32
October	8 47	3 98	9 00	3 20	10 06	5 75	3 15	3 10	6 00	2 20	6 24	2 48
November	4 98	3 95	3 20	3 50	5 22	4 26	3 26	4 07	6 00	5 60	2 37	4 10
December	1 84	3 74	1 10	6 30	6 19	7 92	3 40	1 95	2 80	3 70	2 75	3·87
Totals	52 61	37 34	47·80	35 60	68 98	54 64	30 76	27 53	46 50	35 60	38 18	27 81

SCOTLAND

DIVISION XVIII.—NORTH WESTERN COUNTIES (*continued*)

Ross and Cromarty (*continued*)						Inverness							
Lochbroom		Cromarty		Ardross Castle Alness		Oronsay		Barrahead		Ushenish South Uist		Culloden House	
0 ft 8 in 48 ft.		3 ft 4 in 28 ft		1 ft 0 in 450 ft		0 ft 6 in 1[illegible] ft		3 ft 6 in 40 ft		0 ft 4 in 107 ft		3 ft 0 in 82 ft.	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875
in	in	in	in	in	in	in	in	in	in	in	in	in	in
7 97	4 49	2 13	2 37	3 65	4 82	22 00	4 89	2 79	3 69	7 08	5 10	2 45	2 63
1 76	2 30	06	52	41	1 26	7 20	1 87	1 41	88	2 25	1 85	52	71
6 88	2 72	1 26	98	3 02	2 09	15 25	2 08	2 51	1 04	5 41	1 15	1 71	1 78
4 69	1 84	1 32	16	3 23	1 29	8 72	2 25	1 83	1 24	3 70	2 25	1 60	99
1 45	4 17	1 71	61	3 34	1 78	4 50	4 06	1 29	1 98	2 45	3 10	1 59	86
5 41	3 05	74	78	1 50	2 82	5 85	2 38	86	2 00	2 70	2 05	78	1 58
2 90	4 77	1 39	2 06	2 29	4 32	6 55	2 05	2 85	1 51	2 49	2 00	1 92	3 33
4 25	3 81	3 60	1 52	6 41	3 05	6 95	7 60	3 33	4 30	4 40	6 30	6 40	2 06
4 28	4 05	1 40	2 05	4 00	3 29	10 40	3 23	3 46	1 96	6 65	1 45	2 73	2 65
11 04	2 97	1 74	1 82	5 24	3 45	7 68	2 55	5 15	3 05	6 43	3 70	2 88	1 33
6 12	4 77	1 30	2 25	3 76	3 59	3 75	3 45	3 78	2 94	5 65	4 35	1 71	3 09
4 35	4 19	28	1 77	2 04	3 48	2 30	4 32	1 56	2 37	2 45	2 05	1 02	2 33
61 10	43 13	16 93	16 89	38 89	35 24	101 15	40 73	30 82	26 96	51 66	35 35	25 31	23 34

DIVISION XIX.—NORTHERN COUNTIES (*continued*)

Caithness						Orkney				Shetland			
Nosshead.		Holburnhead		Pentland Skerries		Balfour Castle		Sandwick Manse		Stourhead		Bressay	
3 ft 4 in 127 ft		0 ft 4 in 60 ft		3 ft 3 in 72 ft		0 ft 6 in 50 ft		2 ft 0 in 78 ft				0 ft. 4 in. 60 ft	
1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875.
in	in	in	in	in	in	in	in	in	in	in	in	in	in.
2 71	3 89	4 60	4 50	3 88	4 08	5 00	5 60	3 98	5 02	5 80	6 50	3 43	5 15
66	1 34	70	90	44	1 32	1 20	1 20	1 39	1 99	1 50	3 00	2 33	2·27
2 62	75	3 20	40	2 47	1 00	2 70	50	3 46	83	4 20	5 60	2 92	1·01
1 50	2 08	2 00	3 00	1 31	1 92	1 00	2 20	2 10	2 61	3 70	3 00	3 49	1 60
1 07	1 65	1 80	1 70	69	1 86	60	1 00	1 51	1 51	3 10	5 30	1 34	1 91
99	2 11	1 90	90	1 12	1 81	80	1 00	1 67	1 45	3 20	1 30	2 25	1 44
1 90	2 64	2 00	3 60	1 80	2 20	1 90	2 50	2 75	2 94	2 40	6 90	77	3 98
3 46	2 78	3 70	1 90	2 91	2 68	2 50	2 20	5 00	2 68	4 40	7 40	5 47	3 49
3 56	2 60	2 30	2 10	3 05	2 85	4 60	2 20	4 86	2 86	5 30	4 70	4 29	3 68
3 05	3 09	4 20	2 80	2 27	2 12	3 70	2 20	4 10	3 76	6 50	5 50	4 80	5 55
3 01	3 61	2 50	3 50	2 85	4 16	3 50	4 10	4 00	4 05	4 70	4 80	2 84	4·27
2 84	1 91	2 20	2 30	3 04	1 53	3 20	2 10	3 44	3 36	2 60	8 00	1 98	3 55
27 37	28 45	31 10	27 60	25 83	27 53	30 70	26 80	38 26	33 06	47 40	62 00	35 91	37 90

IRELAND.

	DIVISION XX.—MUNSTER.										DIV. XXI.—LEINSTER.	
	CORK				KERRY.		WATERFORD		CLARE.		CARLOW	
Height of Rain-gauge above	Cork, Queen's College		Fermoy.		Darrynane		Waterford		Gurteen		Fenagh House, Bagnalstown.	
Ground Sea-level	6 ft 0 in. 65 ft		1 ft. 0 in 114 ft.		1 ft 1 in 12 ft		4 ft 6 in 60 ft		1 ft 0 in 267 ft.		1 ft 0 in 340 ft.	
	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875	1874	1875.
	in	in	in	in	in.	in	in	in	in	in	in	in.
January	2 77	7 88	2 46	7 82	5 27	7 36	2 64	7 84	2 61	4 82	3 05	5·76
February	5 41	1 41	5 43	1 35	5 54	2 48	2 98	2 33	1 64	1 04	2 81	2·47
March ..	1 05	1 22	1 68	1 92	3 20	2 35	2 31	1 31	1 90	1 23	1 14	1·60
April	1 64	1 09	2 21	1 63	3 26	3 12	2 61	1 50	1 62	85	1·71	92
May	·18	2 42	98	2 44	1 20	3 31	52	2 61	1 53	1 89	1 34	1 88
June ..	·91	3 01	1 01	2 55	2 34	5 37	1 69	3 27	1 97	3 20	1 80	2 66
July ..	1 27	1 96	2 11	2 09	4 13	2 04	2 40	3 80	2 90	2 27	1·81	2·97
August	1 66	2 41	2 29	1 97	4 41	3 24	3 08	2 28	5 32	2 38	4 65	2·01
September	3 36	6 48	3 93	6 10	5 19	10 61	3 37	5 56	4 18	7 02	2 78	5 15
October .	3 26	6 49	4 08	5 37	6 44	6 96	6 30	9 89	4 04	3·64	4 96	5 59
November ...	3 69	4 21	4·71	4 19	5 28	4 37	5 19	4 44	3 55	2 83	2 96	2·92
December .	5 15	2 28	4 91	2 31	8 17	2·97	4 68	2 03	4 24	2 02	3 82	1 64
Totals	30 35	40 86	35 80	39 74	54 43	54 18	37 77	46 86	35 50	33 19	32 83	35·57

	DIVISION XXII.—CONNAUGHT (*continued*).						DIVISION XXIII.—ULSTER.					
	ROSCOMMON.		MAYO		SLIGO		CAVAN		FERMANAGH		DOWN.	
Height of Rain-gauge above	Holywell.		Cloona Castle		Mount Shannon, Sligo		Red Hills, Belturbet.		Florence Court.		Waringstown.	
Ground . Sea-level.	5 ft. 6 in		2 ft 0 in. 80 ft		4 ft 5 in. 70 ft		0 ft 9 in 208 ft		1 ft 9 in. 250 ft		0 ft. 4 in. 190 ft.	
	1874	1875	1874	1875.	1874.	1875	1874.	1875	1874.	1875	1874.	1875.
	in	in.	in	in	in.	in.	in.	in.	in.	in.	in.	in.
January ...	2 70	3·50	5·10	5 50	4 35	3 97	2 38	5 07	4 06	8 76	1·98	4·33
February .	1 10	1 78	3·10	50	2 40	1·52	1 63	1·53	3·05	1·77	2 20	1·49
March .	3 00	80	2·50	1 50	2 45	1 79	2 09	98	3 18	1 89	1·63	·93
April	1 54	·45	4 80	1 30	3 46	81	2·56	52	4 22	67	1·41	·56
May	2·25	2 20	1 00	3·20	1 78	2 65	1 38	2 49	1 91	3·47	75	1 79
June	1·79	3 15	2 20	3·00	1 58	3 89	1·28	3 58	77	4·16	1·40	3·51
July	2 60	1 75	2 60	1 00	3 80	2 96	2 42	2 64	1·46	1·72	2·46	4·29
August .. .	3·00	3·25	3 90	3·20	4 89	3 77	4 48	3 29	3·35	4 06	4 72	2·63
September	3 72	5 15	5 10	4 00	5 81	3 40	3 30	4 21	6 71	7 55	2·92	3·73
October	2 57	4 85	8 50	3 50	4 95	4 99	4 43	5 22	7 20	7·14	3·66	3·93
November .	3 87	5 68	2 00	3 40	4 26	4·17	3 01	4 57	4 57	4·58	3·29	3·55
December .	3·40	3·65	6·00	3 60	5·83	1 58	3·19	2 55	4 58	4 70	3·24	2·61
Totals	31·54	36 21	46·80	33 70	45·56	35·50	32·15	36·65	45·06	50·47	29·66	[illegible]

IRELAND.

Division XXI.—Leinster (*continued*).										Division XXII.—Connaught.					
Carlow (*continued*)		King's Co.				Wicklow.		Dublin		Galway.					
rown's Hill, Carlow.		Portarlington		Tullamore		Fassaroe, Bray		Glasnevin		Cregg Park		Galway, Queen's College.			
1 ft. 0 in. 291 ft.		1 ft. 2 in 210 ft.		3 ft 0 in 235 ft.		5 ft. 0 in. 250 ft.		0 ft 11 in 65 ft		3 ft 0 in 130 ft		9 ft. 0 in. 30 ft.			
874	1875	1874.	1875	1874	1875	1874	1875.	1874.	1875	1874.	1875	1874.	1875.		
in	in.	in	in.	in	in	in	in.	in	in	in	in.	in	in.		
2·87	5·88	2·31	4·45	1·54	4·62	2·56	5·03	2·00	1·89	3·26	5·22	5·16	5·52		
2·87	2·06	1·54	1·78	1·16	1·44	3·67	3·11	2·27	2·83	2·37	·90	2·68	1·04		
1·18	1·15	1·35	1·32	1·94	·78	1·23	1·70	1·12	·89	2·15	1·08	4·34	1·20		
2·22	·88	1·61	·71	1·89	·81	1·57	1·07	1·34	·76	2·76	1·41	3·07	2·19		
2·08	2·04	1·48	1·74	1·55	1·72	1·70	1·65	1·51	·93	1·59	2·27	3·09	3·68		
1·48	2·54	·82	2·29	·69	3·01	·89	2·47	·23	3·55	2·16	4·35	3·68	3·91		
1·72	3·62	2·73	2·27	3·30	1·60	1·21	3·25	2·67	2·87	3·72	2·47	4·98	1·13		
4·24	1·60	4·19	1·63	3·76	1·98	4·81	1·49	4·24	1·96	6·79	3·52	3·65	3·59		
3·26	4·54	3·51	5·62	3·34	4·86	1·96	5·36	1·82	3·26	6·48	6·90	4·00	1·10		
5·04	6·68	3·26	4·71	3·25	4·49	3·60	8·90	2·58	7·14	6·45	4·39	6·73	3·57		
3·18	3·68	2·81	3·12	2·49	2·94	4·31	5·45	3·09	4·70	3·66	3·10	4·63	2·84		
3·76	1·80	3·41	1·76	3·61	1·59	3·97	1·91	3·42	1·40	4·95	3·23	5·83	2·89		
[illegible]3·90	36·47	29·02	31·40	28·52	29·84	31·48	41·39	26·29	32·18	46·34	38·84	51·84	32·66		

Division XXIII.—Ulster (*continued*).													
Antrim.				Londonderry				Tyrone.		Donegal.			
Agahaleo, Lurgan.		Belfast, Queen's College		Monedig, Garvagh.		Londonderry		Omagh.		Dungloe.		Moville	
1 ft. 0 in. 105 ft.		7 ft. 4 in. 68 ft.		1 ft. 0 in. 121 ft.		0 ft 6 in. 80 ft.		1 ft. 0 in 275 ft.		0 ft 8 in. 10 ft.		4 ft 0 in. 100 ft.	
1874.	1875.	1874	1875	1874.	1875	1874	1875	1874	1875	1874	1875.	1874.	1875.
in.	in.	in	in	in.	in	in.	in	in	in.	in.	in	in.	in.
1·71	4·29	1·88	4·44	2·51	5·82	3·63	3·85	2·07	4·02	4·05	4·20	3·42	4·32
1·98	1·32	2·50	1·06	2·32	1·26	1·70	1·50	1·32	1·28	2·00	1·27	2·44	1·37
1·76	·96	1·69	1·00	2·39	1·93	2·80	1·55	2·81	1·40	3·89	1·75	3·38	2·00
1·49	·51	1·39	·29	2·48	·26	2·85	1·10	2·45	·63	1·61	1·40	2·63	·83
·56	1·97	1·02	·51	1·47	2·05	2·60	3·01	1·93	2·79	2·20	2·97	1·89	2·49
1·41	3·83	1·10	3·05	2·74	2·43	1·42	2·87	3·18	2·64	1·64	3·70	1·64	3·47
2·17	3·35	2·93	3·13	2·79	2·65	3·90	2·80	2·86	2·39	3·21	3·47	4·01	2·22
4·88	2·82	5·04	2·90	5·03	2·87	4·60	2·95	3·26	3·98	6·00	5·55	4·48	3·92
2·51	3·43	3·90	3·77	5·20	4·47	5·70	3·50	4·33	3·94	5·19	2·68	4·84	4·98
4·10	5·35	5·01	4·92	4·40	4·00	6·20	4·97	3·82	5·13	7·05	4·47	5·86	5·41
3·71	3·94	4·92	3·77	4·33	4·99	4·35	4·80	3·19	4·10	4·25	3·61	4·95	7·06
3·75	2·16	3·40	2·14	4·63	2·57	5·10	3·20	4·28	2·50	4·62	3·89	4·86	3·02
[illegible]·93	33·93	34·78	31·98	40·29	35·30	44·85	36·10	35·50	34·80	45·71	38·96	44·40	41·09

Ninth Report of the Committee, consisting of Prof. EVERETT, Sir W. THOMSON, F.R.S., Prof. J. CLERK MAXWELL, F.R.S., G. J. SYMONS, F.M.S., Prof. RAMSAY, F.R.S., Prof. A. GEIKIE, F.R.S., JAMES GLAISHER, F.R.S., GEORGE MAW, F.G.S., W. PENGELLY, F.R.S., Prof. HULL, F.R.S., Prof. ANSTED, F.R.S., Prof. PRESTWICH, F.R.S., Dr. C. LE NEVE FOSTER, Prof. A. S. HERSCHEL, G. A. LEBOUR, F.G.S., *and* A. B. WYNNE, *appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water. Drawn up by* Prof. EVERETT, *Secretary.*

A REMARKABLE series of observations have recently been taken in a boring at Sperenberg, near Berlin. The bore was carried to the depth of 4052 Rhenish (or 4172 English) feet, and was entirely in rock-salt, with the exception of the first 283 feet, which were in gypsum with some anhydrite. The observations were taken under the direction of Herr Eduard Dunker, of Halle an der Saale, and are described by him in a paper occupying thirty-two closely printed quarto pages (206–238) of the 'Zeitschrift für Berg-, Hutten- und Salinen-Wesen' (xx Band, 2 and 3 Lieferung. Berlin, 1872).

The instrument employed for measuring the temperatures was the earth-thermometer of Magnus, which gives its indications by the overflowing of mercury, which takes place when the instrument is exposed to a higher temperature than that at which it was set. To take the reading, it is immersed in water a little colder than the temperature to be measured; the temperature of this water is noted by means of a normal thermometer, and at the same time the number of degrees that are empty in the earth-thermometer is noted. From these data the maximum temperature to which the instrument has been exposed can be deduced, subject to a correction for pressure, which is not very large, because the same pressure acts upon the interior as upon the exterior of the thermometer.

In the following *résumé* (as in the original paper) temperatures are expressed in the Réaumur scale, and depths in Rhenish feet, the Rhenish foot being 1·029722 English foot.

Observations were first taken, at intervals not exceeding 100 feet, from the depth of 100 feet to that of 4042 feet, the temperature observed at the former depth being 11°, and at the latter 38°·5; but all these observations, though forming in themselves a smooth series, were afterwards rejected, on the ground that they were vitiated by circulation of water and consequent convection of heat.

It has often been supposed that though this source of error may affect the middle and upper parts of a bore, it cannot affect the bottom; but the Sperenberg observations seem to prove that no such exemption exists. When the bore had attained a depth of nearly 3390 feet, with a diameter of 12 inches 2 lines at the bottom, an advance-bore of only 6 inches diameter was driven 17½ feet further. A thermometer was then lowered halfway down this advance-bore, and a plug was driven into the mouth of the advance-bore so as to isolate the water contained in it from the rest of the water above. After twenty-eight hours the plug was drawn and the thermometer showed a temperature of 36°·6. On the following day the temperature was observed at the same depth without a plug, and found to be 33°·6. Another observation with the plug was then taken, the thermometer (a fresh instrument) being left twenty-four hours in its position. It registered 36°·5, and again, without plugging, it gave on the same day 33°·9 It thus appears that the effect of convection was to render the temperature in the advance-bore 3° R. too low.

Apparatus was then employed for isolating any portion of a bore by means of two plugs at a suitable distance apart, with the thermometer between them. This operation was found much more difficult than that above described, but in several instances it gave results which were deemed quite satisfactory, while in other instances the apparatus broke, or the plugging was found imperfect The deepest of the successful observations by this method was at 2100 feet, and the shallowest was at 700 feet. The first 444 feet of the bore were lined with iron tubes, between which the water had the opportunity of circulating even when the innermost tube was plugged, hence the observations taken in this part were rejected.

All the successful observations are given in the third column of the following Table, subject to a correction for pressure; and, for the sake of showing the error due to convection in the ordinary mode of observing, the temperatures observed at the same depths when no plugs were used are given in the second column.—

Depth in feet	Temperature Réaumur		Difference
	Without plugging	With plugging	
700	16°·08	17°·06	0°·98
900	17·18	18·5	1·32
1100	19·08	20·8	1·72
1300	20·38	21·1	0·72
1500	22·08	22·8	0·72
1700	22·9	24·2	1·3
1900	24·8	25·9	1·1
2100	26·8	28·0	1·2
3300	34·1	36·15	2·05

These temperatures are not corrected for pressure, but they are corrected for rise of zero in the normal thermometer; and this last circumstance explains the difference of 0·4 between the temperature 36°·15 here given and 36°·55, which is the mean of the above-mentioned observations at the depth of 3390 feet.

Another proof of the injurious effect of convection was obtained by comparing the observed temperatures (without plugging) in the first 400 feet of the great bore, designated Bore I., with the temperatures observed at the same depths during the sinking of another bore, designated Bore II., near it, the observations in this latter being always taken at the bottom. The following were the results —

Depth in feet.	Temperature	
	Bore I	Bore II.
100	11°·0	9°·0
200	11·6	10·4
300	12·3	11·5
400	13·6	12·5

The temperature at the depth of 100 feet in the great bore thus appears to have been raised about 2° R by convection.

The following is a Table of the successful observations, corrected for pressure:—

Depth in Rhenish feet	Temperature Reaumur.
700	17°·275
900	18·780
1100	21·147
1300	21·510
1500	23·277
1700	24·741
1900	26·504
2100	28·668
3390	37·238

Assuming, with Herr Dunker, the mean temperature of the surface to be 7° 18, which is the mean annual temperature of the air at Berlin, we have the following increments of temperature with depth :—

Depths in Rhenish feet.	Increment of depth	Increment of temperature	Increase per 100 feet deg Reau.	Increase per 100 feet deg Fahr
0 to 700	700	10°·095	1°·442	3°·24
700 to 900	200	1·505	·752	1·69
900 to 1100	200	2·367	1·184	2·66
1100 to 1300	200	0·363	·182	·41
1300 to 1500	200	1·767	·884	1·99
1500 to 1700	200	1·464	·732	1·65
1700 to 1900	200	1·763	·882	1·98
1900 to 2100	200	2·164	1·082	2·43
2100 to 3390	1290	8·570	·664	1·49
0 to 3390	3390	30·058	·887	2·00

The mean rate of increase found by comparing the temperatures at the surface and 3390 feet is exactly 1° Fahr. for 50 Rhenish or 51·5 English feet.

The numbers in the last two columns exhibit upon the whole a diminution with increase of depth, in other words, the temperature increases less rapidly as we go deeper down. As regards the first 700 feet, which exhibit a decidedly more rapid rate than the rest, it must be remembered that nearly half of this distance was in a different material from the rest of the bore, being in gypsum with some anhydrite, while all the rest was in rock-salt. Prof. Herschel has found, in recent experiments not yet published, that the conductivity of rock-salt is exceedingly high, and theory shows that the rates of increase, in superimposed strata, should be inversely as their conductivities. We may therefore fairly attribute the rapid increase in the first 700 feet to the relatively small conductivity of the portion (283 feet) which is not rock-salt. The slow rate of increase observed in the long interval between the depths of 2100 and 3390 feet is not so easily accounted for; we can only conjecture that this and the other inequalities which the above Table presents, for depths exceeding 700 feet, are due to fissures or other inequalities in the rock which have not been put in evidence.

With the view of summing up his results in small compass, Herr Dunker has assumed the empirical formula—

$$t = 7{\cdot}18 + ax + bx^2,$$

t denoting the temperature (Réaumur) at the depth x (Rhenish feet), and has computed the most probable values of a and b by the method of least squares. He finds

$$a = \cdot0129857 \qquad b = -\cdot00000125791,$$

the negative sign of b indicating that the increase of temperature becomes slower as the depth increases.

A paper by Prof. Mohr, of Bonn, as represented by an abstract published in 'Nature' (vol. xii p. 545), has attracted attention from the boldness of its reasoning in reference to the Sperenberg observations. Prof Mohr, however, does not quote the observations themselves, but only the temperatures calculated by the above formula, which he designates, in his original paper ('Neues Jahrbuch fur Mineralogie,' &c., 1875, Heft 4), "the results deduced from the observations by the method of least squares." In the abstract in 'Nature' they are simply termed "the results of the thermometric investigation of the Sperenberg boring," a designation which is still more misleading.

Attention is called to the circumstance that the successive increments of temperature for successive equal increments of depth form an exact arithmetical progression, as if this were a remarkable fact of observation, whereas it is merely the result of the particular mode of reduction which was adopted, being a mathematical consequence of the assumed formula—

$$t = 7{\cdot}18 + ax + bx^2.$$

The method of least squares is not responsible for this formula, but merely serves, after this formula has been assumed for convenience, to give the best values of a and b.

Herr Dunker, in his own paper, lays no stress upon the formula, and gives a caution against extending it to depths much greater than those to which the observations extend. Writing to Prof. Everett under date April, 1876, he requests that, in the summary of his results to be given in the present Report, the formula should either be suppressed or accompanied by the statement that its author reserves a different deduction.

The following are the differences between the temperatures computed by the formula and the observed temperatures:—

Depth.	Difference (computed *minus* observed)
700	$-1^\circ{\cdot}621$
900	$-1{\cdot}931$
1100	$-1{\cdot}204$
1300	$+0{\cdot}427$
1500	$+0{\cdot}553$
1700	$+0{\cdot}882$
1900	$+0{\cdot}811$
2100	$+0{\cdot}238$
3390	$-0{\cdot}482$

The necessity of adopting some means to prevent the circulation of water in bores has for some time been forcing itself upon the attention of your Committee. Many of the observations taken by their observers have contained such palpable evidence of convection as to render them manifestly useless for the purpose intended; and in the light of the Sperenberg experiments it is difficult to place much reliance on any observations taken in deep bores without plugging. The selection of a suitable form of plug is now occupying the careful attention of your Committee.

Herr Dunker's paper gives a very full account of the different kinds of plug employed at Sperenberg.

For stopping the mouth of the advance-bore the plug had a tapering shape, and was of hard wood, strengthened by two iron rings, one at each end, and covered with a layer of tow 5 lines thick, outside of which was thick and strong linen, nailed above and below to the wood through a leather strap. It was lowered into its place by means of the iron rods used for boring; and, when in position was pressed home by a portion of the weight of the rods. The plug carried the thermometer suspended from it. Its extraction was commenced by means of a screw on the beam of the boring-machine, in order to avoid a sudden jerk, which might have broken the thermometer. The force which was found necessary for thus starting the plug, as well as the impression observed upon it when withdrawn, showed that it had fitted tight. To insure a good fit, the top of the advance-bore had been brought to a suitable shape, and its inequalities removed, by means of a revolving cutting-tool. Herr Dunker remarks that this plan is adapted to a soft material like rock-salt, but that in ordinary hard rock it would be better to make the bottom of the main bore flat, and to close the advance-bore by an elastic disk pressed over it. The method of observation by advance-bores can only be employed during the sinking of the bore, a time when it is difficult to avoid error arising from the heat generated in boring. The expense of making an advance-bore at each depth at which an observation is required is also an objection to its use.

Another kind of plug devised by Herr Dunker, and largely used in the observations, consisted of a bag of very stout india-rubber (9 millimetres thick) filled with water, and capable of being pressed between two wooden disks, one above and the other below it, so as to make it bulge out in the middle and fit tightly against the sides of the bore. On the suggestion of bore-inspector Zobel, the pressure was applied and removed by means of screwing Two steel springs fastened to the upper disk, and appearing, in Herr Dunker's diagram, very like the two halves of a circular hoop distorted into an oval by pressing against its walls, prevented the upper disk from turning, but offered little resistance to its rising or falling. The lower disk, on the contrary, was permitted to turn. Both disks were carried by the iron boring-rods. Rotation of these in one direction screwed the disks nearer together, and rotation in the other direction brought them further apart. The india-rubber bag could thus be made to swell out and plug the bore when it was at the desired depth, and could be reduced to its original size for raising or lowering. In order to prevent the boring-rods from becoming unscrewed one from another, when rotated backwards, it was necessary to fasten them together by clamps, a rather tedious operation in working at great depths.

In taking observations at other points than the bottom, two of these plugs were employed, one above and the other below the thermometer.

In some of the experiments, the apparatus was modified by using linen bags filled with wet clay, instead of india-rubber bags filled with water; and, instead of screwing, direct pressure was employed, the lower disk being supported by rods extending to the bottom of the bore, while the upper disk could be made to bear the whole or a portion of the weight of the rods above it. Some successful observations were obtained with both kinds of bag; but the water-bags were preferred, as returning more easily to their original size when the pressure was removed, and consequently being less liable to injury in extraction. In some observations since taken in another place (Sudenberg), Herr Dunker states (in the private letter above referred to) that india-rubber bags, filled with water, and pressed, not by screwing, but by the weight of the rods, were employed with much satisfaction

All the methods of plugging employed by Herr Dunker involved the use of the iron rods belonging to the boring-apparatus and therefore would be inapplicable (except at great expense) after the operation of boring is finished and the apparatus removed

It seems desirable to contrive, if possible, some plug that can be let down and raised by a wire In the first report of your Committee, it was suggested that two bags of sand, one above and the other below the thermometer, should be used for this purpose Bags of sand however would be liable to rub off pieces from the sides of the bore, and thus to become jammed in drawing up Mr Lebour has devised a plug which will be of small diameter during the processes of lowering and raising but can be rendered large and made to fit the bore, when at the proper depth by letting down upon it a sliding weight suspended by a second wire Sir W Thomson suggests that a series of india-rubber disks, at a considerable distance apart, will probably be found effectual

Mr Boot has continued his observations in the bore which he is making at Swinderby, near Scarle (Lincoln) It has now been carried to the depth of 2000 feet, and is in earthy limestone or calcareous shale of Carboniferous age Its diameter in the lower part is only 3⅛ inches In April last the temperature 78° F was observed at 1950 feet and more recently 79° F was observed at 2000 feet—the water in each case, having been undisturbed for a month Supposing these results not to be vitiated by convection, and assuming the mean temperature at the surface to be 50° we have an increase of 29° in 2000 feet, which is at the rate of 1° in 69 feet

Mr Symons has taken a series of observations at the depth of 1000 feet in the Kentish Town well, with the view of determining whether the temperature changes The instrument employed is a very large and delicate Phillips's maximum thermometer The following is a list of the observations —

Date of lowering		Depth indicated	Thermometer set at	Date of raising		Depth indicated	Temperature Fahr
		feet	°			feet	°
1874	—	1000	64 50	1874,	May 8	1007	66 82
	May 8	1000	63 80		July 2	1009	(reading lost)
	July 2	1000	63 20		July 28	1005	67 40
	July 28	1000	65 10		Sept 8	1004	67 51
	Sept 8	1000	65 80		Sept 29	1004	67 43
	Sept 29	1000	65 81		Oct 30	1006	67 68
	Oct. 30	1000	63 40		Dec 3	1006	67 52
	Dec 3	1000	63 80	1875	Jan 7	1009	67·63
1875	Jan 7	1000	63 70		Feb 1	1006	67 56
	Feb 1	1000	63 90		Mar 3	1005	67 53
	Mar 3	1000	63·90		May 3	1006	67 62
	May 3	1000	63 95		June 1	1005	67 49
	June 1	1000	63·00		July 7	1005	67 53
	July 7	1000	63 87		Aug 3	1004	67 58
	Aug 3	1000	63 87		Sept 10	1004	67 58
	Sept. 10	1000	64 00		Oct 2	1003	67 58
	Oct. 2	1000	63 90		Oct 19	1004	67·62
	Oct. 19	1000	63 80		Nov 1	1005	67 62
	Nov 1	1000	63 70		Dec 1	Wire broke	

The "depth indicated" is shown by a measuring wheel or pulley, over which the wire runs by which the thermometer is raised and lowered, as described, with a diagram, in the Report for 1869. The above Table shows that there is always some stretching, real or apparent, in the interval between lowering the thermometer and raising it again. Recent observations, by means of a fixed mark on the wire, have shown that the change is not, in the main, a permanent elongation, but an alternation of length. It is probably due in part to the greater tension which the wire is under in raising than in lowering, a circumstance which will cause a temporary difference of length variable with the rapidity of winding up; also in part to the circumstance that the wire is warmer when it has just left the water than when it is about to be let down. Some portion of the irregularity observed may be due to variations of temperature in that part of the well (210 feet) which contains air The observations, taken as a whole, show that any variations of temperature which occur in this well at the depth of 1000 feet are so small as to be comparable with the almost inevitable errors of observation. The observations will be continued at intervals of six months, with additional precautions, and with an excessively slow (specially constructed) non-registering thermometer, in addition to the maximum thermometer hitherto employed.

Through the kindness of the eminent geologist M. Delesse, of the École Normale at Paris, observations have been obtained from the coal-mines of Anzin, in the north of France. They were taken under the direction of M. Marsilly, chief engineer of these mines. Maximum thermometers of the protected Negretti pattern were inserted in holes bored horizontally to the depth of ·6 or ·7 of a metre in the sides of shafts which were in process of sinking, and in which there was but little circulation of air. A quarter of an hour was allowed to elapse in each case, after the boring of the hole, before the thermometer was inserted and the hole plugged. Four different shafts were tried. Those designated as Nos. I., II., III. were in the mine Chabaud La Tour, and No. IV. was in the mine Renard.

In shaft I. observations were taken at eight different depths, commencing with the temperature 56½° F. at a depth of 38·5 metres, and ending with 67¾° F. at 200·5 metres.

In shaft II there were observations at four depths, commencing with 55° at 87·3 m., and ending with 63½° at 185 m.

In shaft III. there were observations at three depths, commencing with 56° at 87·8 m., and ending with 62⅛° at 144 m.

These three shafts, all belonging to the same mine, were very wet, and the temperature of the air in them was 11° or 12° C. (52° or 54° F.).

In shaft IV., which was very dry and had an air temperature of about 15° C. (59° F.), observations were taken at six depths, commencing with 70¾° F. at 21·2 m., and ending with 84° F. at 134·8 m.

The mean rates of increase deduced from these observations are:—

In Shaft	I.,	1° F. in	14·4 m.,	or in	47·2 feet.
,,	II.,	,,	11·5 m.,	,,	37·7 ,,
,,	III.,	,,	8·65 m.,	,,	28·4 ,,
,,	IV.,	,,	8·57 m.,	,,	28·1 ,,

The observer mentions that in shaft II. there was, at a depth of 90 m., a seam of coal in which heat was generated by oxidation; but no such remark is made with respect to any of the other shafts, although it is obvious that some disturbing cause has rendered the temperature in shaft IV. abnormally high. Possibly the heat generated in boring the holes for the thermometers in this shaft (which was dry) has vitiated the observations, the instruments employed being maximum thermometers. Two of the slow non-registering thermometers mentioned in last year's Report have been sent to M. Delesse, to be used for verification.

The slow-action thermometers are constructed on the following plan:—The bulb is cylindrical and very strong, and is surrounded by stearine or tallow, which fills up the space between it and a strong glass shield in which the thermometer is inclosed. The shield is not hermetically sealed (not being intended for protection against pressure), but is stopped at the bottom with a cork, so that the thermometer can be taken out and put in again if desired. Stearine and tallow were selected after trials of several substances, including paraffin-wax, bees'-wax, glue, plaster of Paris, pounded glass, and cotton-wool. The thermometers are inclosed in copper cases lined with india-rubber. When placed, without these cases, in water differing 10° from their own temperature, they take nearly half a minute to alter by one tenth of a degree.

In concluding this Report, your Committee desire to express their regret at the losses which they have sustained by the deaths of Prof. Phillips, Sir Charles Lyell, and Col. Strange, of whose valuable services they have been deprived within the last three years.

Nitrous Oxide in the Gaseous and Liquid States.

By W. J. Janssen.

[A communication ordered by the General Committee to be printed *in extenso*.]

The experiments of Faraday on the liquefaction of gases have already proved that gases at the ordinary conditions of pressure and temperature are vapours at a remote stage from their points of condensation. If several gases submitted to great pressure and the cold of the carbonic acid and ether bath did not exhibit any appearance of liquefaction, the cause is probably that Faraday did not obtain a temperature low enough to produce liquefaction. Hence we may conclude that the gaseous and liquid states of matter depend only on the temperature and pressure to which it is exposed. The interesting experiments of Dr. Andrews with carbonic acid (Philosophical Transactions for 1869) not only verified this conclusion, but gave the important result that gases and liquids are distant stages of the same condition of matter, which may pass into one another without breach of continuity. The temperature at which matter, without sudden change of volume or abrupt absorption of heat, passes from the ordinary liquid to the ordinary gaseous state is called by Dr. Andrews the critical point, above that temperature a gas never can be liquefied by pressure, it behaves like a permanent gas; below that temperature it will be liquid or gas, or more exactly liquid or vapour, according to the pressure to which it is exposed. For the details I refer to the above-mentioned paper.

I have made the same kind of experiments with nitrous oxide, a gas whose physical properties agree much with those of carbonic acid. The apparatus was similar to that used by Dr. Andrews, to whom I am much indebted for the great kindness with which he has afforded me every instruction, and for his invaluable advice about the use of his apparatus during my stay at Belfast and afterwards.

As my experiments with nitrous oxide presented anomalies which did not occur with carbonic acid, I first made some experiments with the latter gas, in order to try whether they were to be ascribed to observational errors or to the nitrous oxide I used. The results are given in the following Tables, where δ is the fraction representing the ratio of the volume of the air after and before compression to one another at the temperature t, ϵ the corresponding fraction for the carbonic acid at the temperature t', and l the number of volumes which 17,000 volumes of carbonic acid, measured at 0° and 760 millims., would occupy at the temperature and pressure of the observation. The number 17,000 has been taken as unit to compare these Tables with those of Andrews.

Table I.—Carbonic Acid at 21°·45 C.

δ.	t	ϵ	t'.	l.
$\frac{1}{58\cdot70}$	13°·18	$\frac{1}{105\cdot70}$	21°·44	173·6
$\frac{1}{59\cdot81}$	13·18	$\frac{1}{113\cdot20}$	21·47	162·1
$\frac{1}{60\cdot02}$	12·26	$\frac{1}{164\cdot20}$	21·41	111·7
$\frac{1}{61\cdot11}$	12·26	$\frac{1}{50\cdot40}$	21·49	52·4
$\frac{1}{62\cdot18}$	12·46	$\frac{1}{427\cdot13}$	21·50	42·9

Table II.—Carbonic Acid at 31°·15 C.

δ	t.	ϵ	t'	l.
$\frac{1}{64\cdot52}$	10°·31	$\frac{1}{109\cdot20}$	31°·20	173·6
$\frac{1}{67\cdot82}$	10·06	$\frac{1}{124\cdot6}$	31·12	152·4
$\frac{1}{69\cdot43}$	10·60	$\frac{1}{134\cdot79}$	31·19	142·8
$\frac{1}{70\cdot60}$	10·49	$\frac{1}{140\cdot21}$	31·13	135·2
$\frac{1}{72\cdot08}$	10·97	$\frac{1}{155\cdot76}$	31·11	121·7
$\frac{1}{73\cdot36}$	10·36	$\frac{1}{168\cdot11}$	31·18	112·8
$\frac{1}{74\cdot80}$	10·52	$\frac{1}{206\cdot69}$	31·14	91·7
$\frac{1}{75\cdot20}$	10·65	$\frac{1}{293\cdot37}$	31·13	64·6
$\frac{1}{78\cdot86}$	10·30	$\frac{1}{370\cdot84}$	31·19	51·1
$\frac{1}{84\cdot40}$	10·36	$\frac{1}{397\cdot70}$	31·15	47·4

These results agree closely with the experiments of Dr Andrews at the corresponding temperatures, the differences being only 0·2 of an atmosphere. At 21°·47 the gas passed into the liquid state at a pressure of 59·8 atmospheres, whilst its volume had diminished from 17,000 to 162; with Dr. Andrews this pressure amounted to 60·05 atmospheres, and the corresponding volume of the carbonic acid to 160. As the quantity of *air* in my case was about $\frac{1}{100}$ of the entire volume of the gas, the increase of pressure to liquefy the whole after liquefaction had begun, amounted to about 2·4 atmospheres, viz. from 59·81 to 62·18. The critical temperature I found to be 30°·87. It will be observed that the pressures are those indicated by the apparent contraction of the air in the air-tube.

In the following Tables δ and ϵ have the same meaning as before, but applied to nitrous oxide; *l*, however, represents the number of volumes which 1000 volumes of nitrous oxide, measured at 0° and 760 millims., would occupy at the temperature and pressure of the observation. The experiments were made at the temperatures of 25°·15, 32°·2, 36°·4, 38°·4, and 43°·8, two series below, and three above, the critical point, which was found to vary between 36°·3 and 36°·7. The appearances were the same as with carbonic acid.

Table I.—Nitrous Oxide at 25°·15

δ	*t*.	ϵ	*t'*.	*l*
$\frac{1}{51{\cdot}50}$	°5·51	$\frac{1}{78{\cdot}97}$	°25·09	13·83
$\frac{1}{56{\cdot}15}$	5·26	$\frac{1}{95{\cdot}01}$	25·11	11·50
$\frac{1}{57{\cdot}83}$	5·73	$\frac{1}{103{\cdot}50}$	25·16	10·56
$\frac{1}{59{\cdot}44}$	4·98	$\frac{1}{140{\cdot}90}$	25·19	7·44
$\frac{1}{60{\cdot}76}$	4·98	$\frac{1}{218{\cdot}90}$	25·19	5·04
$\frac{1}{63{\cdot}84}$	4·98	$\frac{1}{302{\cdot}29}$	25·19	3·61
$\frac{1}{66{\cdot}80}$	4·55	$\frac{1}{348{\cdot}84}$	25·19	3·10
$\frac{1}{70{\cdot}50}$	5·02	$\frac{1}{391{\cdot}73}$	25·14	2·77
$\frac{1}{72{\cdot}92}$	4·98	$\frac{1}{412{\cdot}36}$	25·19	2·65
$\frac{1}{73{\cdot}65}$	4·98	$\frac{1}{419{\cdot}16}$	25·19	2·61
$\frac{1}{76{\cdot}04}$	4·12	$\frac{1}{423{\cdot}24}$	25·19	2·57
$\frac{1}{84{\cdot}85}$	4·16	$\frac{1}{431{\cdot}85}$	25·19	2·53

Table II.—Nitrous Oxide at 32°·2

δ	*t*	*e*	*t*	*l*
$\frac{1}{15\cdot11}$	8°·07	$\frac{1}{60\ \ 1}$	32°·17	18·62
4 8	7 53	$\frac{1}{6\ \ 21}$	32·28	17·16
$\frac{1}{51\cdot29}$	6·82	$\frac{1}{7\ \ 73}$	32·21	15·33
$\frac{1}{55\cdot70}$	5·49	$\frac{1}{81\ \ 3}$	32·18	13·24
$\frac{1}{5\ \ 4}$	5·39	$\frac{1}{90\cdot19}$	32·21	12·41
$\frac{1}{6\ \ 1}$	5·11	$\frac{1}{0}$	32·21	10·42
$\frac{1}{64\cdot86}$	5·26	$\frac{1}{118\ \ 7}$	32·1	9·45
$\frac{1}{67\cdot45}$	6·50	$\frac{1}{138\cdot63}$	32·28	8·07
$\frac{1}{6\ \ 63}$	5·73	$\frac{1}{140\ \ 0}$	32·20	7·95
$\frac{1}{68\cdot13}$	4·30	$\frac{1}{160\cdot65}$	32·29	6·71
$\frac{1}{69\cdot92}$	4·30	$\frac{1}{214\cdot15}$	32·23	5·23
$\frac{1}{73\cdot87}$	4·30	$\frac{1}{7\ 05}$	32·21	4·04
$\frac{1}{76\cdot29}$	4·30	$\frac{1}{345\cdot91}$	32·26	3·23
$\frac{1}{8\ \ 11}$	4 5	$\frac{1}{8\ \ 93}$	32·21	2·93
$\frac{1}{84\ \ 8}$	4 1	36 42	32·21	2·82
$\frac{1}{85\cdot92}$	4 1	$\frac{1}{1\ 3\ \ 0}$	32 3	2·78
$\frac{1}{91\cdot31}$	4·51	11 1	32·21	2·71
$\frac{1}{94\cdot36}$	4·60	$\frac{1}{418\cdot13}$	32·11	2·67
$\frac{1}{101\ \ 3}$	7 3	$\frac{1}{4\ 5\ 03}$	32·46	2·64
117·04	7·73	$\frac{1}{413\cdot16}$	32·48	2·52

TABLE III.—Nitrous Oxide at 36°·4

δ	p		t	l
$\frac{1}{66\cdot41}$	3·41	$\frac{1}{110\cdot87}$	36°·39	10·23
$\frac{1}{69\cdot51}$	3·67	$\frac{1}{130\cdot43}$	36·41	8·[illegible]
$\frac{1}{\text{[illegible]}2\cdot41}$	3·12	$\frac{1}{1\text{[illegible]}1\cdot32}$	36·40	7·50
$\frac{1}{73\cdot07}$	4·90	$\frac{1}{1\text{[illegible]}9\cdot4\text{[illegible]}}$	36·41	7·12
$\frac{1}{\text{[illegible]}4\cdot92}$	[illegible]·42	$\frac{1}{\text{[illegible]}08\cdot20}$	3[illegible]·39	5·4[illegible]
$\frac{1}{76\cdot\text{[illegible]}1}$	4·63	$\frac{1}{\text{[illegible]}46\cdot\text{[illegible]}5}$	36·37	4·63
$\frac{1}{\text{[illegible]}78}$	4·68	28[illegible]·1	[illegible]·10	4·02
$\frac{1}{8\text{[illegible]}\cdot60}$	4·7[illegible]	[illegible]	3[illegible]·33	3·68
$\frac{1}{80\cdot05}$	4·[illegible]0	$\frac{1}{345\cdot\text{[illegible]}0}$	36·38	3·23
$\frac{1}{85\cdot46}$	4·94	$\frac{1}{369\cdot42}$	36·3[illegible]	3·07
$\frac{1}{89\cdot62}$	4·75	$\frac{1}{383\cdot56}$	3[illegible]·3[illegible]	2·[illegible]6
$\frac{1}{96\cdot25}$	6·80	$\frac{1}{397\cdot99}$	36·37	2·85
$\frac{1}{100\cdot74}$	7·41	$\frac{1}{411\cdot51}$	36·37	2·75
$\frac{1}{106\cdot01}$	7·49	$\frac{1}{420\cdot85}$	36·37	2·69
$\frac{1}{116\cdot22}$	7·54	$\frac{1}{431\cdot35}$	36·38	2·63

TABLE IV —Nitrous Oxide at 38° 4

	t	e	t	t
$\frac{1}{6\ \ 4}$	5 7[illegible]	$\frac{1}{78\ \ 9}$	38 3	14 19
0 86	6 48	1 1 6	38 38	[illegible]
$\frac{1}{7\ \ 49}$	4 [illegible]1	11 6	38 3[illegible]	7 85
$\frac{1}{5\ 13}$	6 50	$\frac{1}{160\ 56}$	38 37	7 11
$\frac{1}{76\ \ 7}$	4 3[illegible]	$\frac{1}{6\ \ 8}$	38 39	6 47
$\frac{1}{80}$	6 59	$\frac{1}{20\ \ 11}$	38 37	5 07
$\frac{1}{70\ \ 9}$	4 89	$\frac{1}{224\ 94}$	38 45	5 08
$\frac{1}{82\ 10}$	4 85	$\frac{1}{302\ 81}$	38 4[illegible]	3 77
$\frac{1}{84\ 68}$	4 08	$\frac{1}{336\ 07}$	38 40	3 39
$\frac{1}{87\ 13}$	[illegible] 19	$\frac{1}{6}$	38 33	3 20
99 9	[illegible] 48	$\frac{1}{96\ \ 2}$	38 31	2 87
$\frac{1}{111\ 87}$	8 22	$\frac{1}{419\ 31}$	38 40	2 72
$\frac{1}{122\ 30}$	7 [illegible]	$\frac{1}{43[illegible]\ 91}$	38 35	2 64
$\frac{1}{15[illegible]\ 87}$	8 19	$\frac{1}{460\ 87}$	38 30	2 48
$\frac{1}{1[illegible]2}$	5 84	$\frac{1}{461\ 18}$	38 55	2 47

TABLE V.—Nitrous Oxide at 43°·8.

δ	ϵ	c	t'	l
$\frac{1}{65·29}$	5·91	$\frac{1}{100·72}$	43·81	11·54
$\frac{1}{73·1}$	6·18	$\frac{1}{127·[illegible]8}$	43·90	9·10
$\frac{1}{80·83}$	6·45	$\frac{1}{170·03}$	43·80	6·84
$\frac{1}{84·37}$	8·80	$\frac{1}{209·18}$	43·81	5·55
$\frac{1}{90·05}$	7·69	$\frac{1}{289·11}$	43·76	4·02
$\frac{1}{94·40}$	7·55	$\frac{1}{329·59}$	43·88	3·52
$\frac{1}{103·84}$	7·61	$\frac{1}{375·16}$	43·71	3·09
$\frac{1}{12[illegible]·01}$	7·79	$\frac{1}{416·49}$	43·75	2·79

Comparing these results for nitrous oxide with those for carbonic acid found by Dr. Andrews, we find the compressibility of the two gases nearly the same at temperatures equidistant from their critical points. At the temperature of 25°·16, liquefaction begins under a pressure of 57·83 atmospheres; at 32°·28, the gas passes into the liquid state under a pressure of 67·45 atmospheres; at this point a great diminution of volume occurs, but not abruptly as in the case of carbonic acid; this must be ascribed to the presence of a greater quantity of a permanent gas in the nitrous oxide.

In the liquid state, nitrous oxide yields as much to pressure as carbonic acid; the rate of expansion by heat will be therefore very great. This is a confirmation of the results of Drion (Ann. de Chim. et de Phys. t. lvi. p. 37), that the coefficient of expansion of volatile liquids at a temperature still below the critical point grows equal to the coefficient of expansion of gases and increases further, till at the critical point it may attain to a value any number of times greater than that of air.

At temperatures above the critical point, the volume of nitrous oxide diminishes with tolerable regularity with increase of pressure, though much faster than according to the law of Boyle; the higher the temperature the more the compressibility approaches to that of a perfect gas. When the gas is reduced to the volume at which it might be expected to liquefy, no trace of liquid is to be seen, the whole mass of the gas remaining homogeneous; but a rapid diminution of volume occurs from a small increase of pressure; this diminution of volume is not abrupt as in the case of liquefaction, and diminishes greatly at higher temperatures.

The anomalies presented by nitrous oxide were:—

1. Under a given pressure and temperature the volume of the compressed gas is variable, or *vice versâ*. This anomaly is very obvious in that condition of matter where a rapid diminution of volume occurs at a small increase of pressure; under a given volume of the gas the difference of pressure can amount here to 2 atmospheres, in the other cases this difference is very slight, about 0·2 to 0·4 of an atmosphere. This appears from the following results:—

c	t		t	L
$\frac{1}{44\ 97}$	8° 26	$\frac{1}{63\ 55}$	25° 01	17 46
$\frac{1}{4\ 21}$	7 13	$\frac{1}{6\ 64}$	25 0[illegible]	17 44
$\frac{1}{5\ 3}$	8 47	$\frac{1}{8\ 99}$	25 09	13 83
$\frac{1}{51\ 50}$	4 19	$\frac{1}{78\ 4}$	25 09	13 84
$\frac{1}{51\ 62}$	3 87	$\frac{1}{78{\cdot}98}$	25 03	13 83
$\frac{1}{55\ 73}$	10 37	$\frac{1}{91\ 13}$	25 21	11 62
$\frac{1}{56\ 01}$	8 20	$\frac{1}{94\ 0}$	25 30	11 61
$\frac{1}{78\ 41}$	5 14	$\frac{1}{309\ 64}$	36 35	3 66
$\frac{1}{78\ 80}$	4 66	$\frac{1}{309\ 08}$	36 37	3 67
$\frac{1}{89{\cdot}08}$	8 67	$\frac{1}{383\ 41}$	36 40	2 96
$\frac{1}{90\ 31}$	4 98	$\frac{1}{383\ 67}$	36 40	2 96
$\frac{1}{100\ 12}$	7 71	$\frac{1}{411\ 56}$	36 42	2 76
$\frac{1}{102\ 05}$	7 07	$\frac{1}{411\ 83}$	36 35	2 75
$\frac{1}{70\ 73}$	7 43	$\frac{1}{131\ 54}$	38 37	8 68
$\frac{1}{71\ 01}$	5 43	$\frac{1}{131\ 57}$	38 40	8 68
$\frac{1}{77\ 25}$	5 70	$\frac{1}{205\ 05}$	38 29	5 56
$\frac{1}{77\ 75}$	8 37	$\frac{1}{205\ 09}$	38 35	5 56
$\frac{1}{78\ 06}$	4 81	$\frac{1}{197\ 13}$	38 40	5 79

2 The pressure required to liquefy the nitrous oxide and the volume of this gas at the beginning of liquefaction are variable

The pressure required to liquefy the gas at 25° 15 recorded in Table I is the mean of the following observations —

δ	t		t	l
$\frac{1}{58\ 70}$	4 57	$\frac{1}{1\ 8\ 08}$	25° 17	10 11
$\frac{1}{5\ 95}$	4 93	1 4 0	25 18	10 51
$\frac{1}{57\ 83}$	4 38	$\frac{1}{103\ 68}$	25 1[illegible]	10 54
$\frac{1}{57\ 8}$	4 34	$\frac{1}{5}$	25 1[illegible]	10 68
$\frac{1}{57\ 29}$	8 65	$\frac{1}{101\ 1}$	25 0[illegible]	10 81
$\frac{1}{57\ 42}$	7 54	$\frac{1}{101\ 84}$	25 13	10 74

The following series of experiments was performed in the course of a day —

δ	t	e	t	l
$\frac{1}{58\ 86}$	7° 84	$\frac{1}{111\ 38}$	25 34	0 82
$\frac{1}{58\ 78}$	7 50	$\frac{1}{1\ 7\ 93}$	25 24	10 14
$\frac{1}{59\ 16}$	7 51	$\frac{1}{1\ 9\ 7}$	25 57	10 03
$\frac{1}{5\ 53}$	7 82	$\frac{1}{101\ 40}$	25 23	10 78
$\frac{1}{57\ 57}$	8 47	$\frac{1}{108\ 52}$	25 40	10 57
$\frac{1}{57{\cdot}84}$	8 40	$\frac{1}{103\ 45}$	25 24	10 58
$\frac{1}{57\ 80}$	8 41	$\frac{1}{103\ 35}$	25 30	10 58
$\frac{1}{58\ 12}$	8 41	$\frac{1}{104\ 50}$	25 30	10 40
$\frac{1}{5\ 10}$	8 44	$\frac{1}{1\ 8\ 00}$	25 35	10 61

At 32°·2 the greatest difference of pressure amounted to 2 atmospheres, as appears from the next series of experiments

δ	t	ϵ	t'	l
$\frac{1}{66.95}$	6.96	$\frac{1}{134.00}$	32°.21	8.35
$\frac{1}{68.91}$	5.67	$\frac{1}{172.5}$	32.21	7.12
$\frac{1}{67.85}$	5.75	$\frac{1}{111.74}$	32.21	7.89
$\frac{1}{67.79}$	7.43	$\frac{1}{139.07}$	32.61	8.05

3. After liquefaction has begun an increase of pressure of 16 atmospheres or more is required to liquefy the whole mass of the nitrous oxide; for at 25°·17 liquefaction began at a pressure of 57.83 atmospheres, whilst the whole was liquid at a pressure of 73.68 atmospheres. At 32°·2 I found the commencement of liquefaction at a pressure of 67.63 atmospheres, and the termination at a pressure of 84.09 atmospheres. For carbonic acid, that was mixed with $\frac{1}{500}$ to $\frac{1}{1000}$ of air, the increase of pressure amounted to 1·5 atmosphere. Had the gas been pure no increase of pressure could have occurred. This shows that a greater quantity of a permanent gas must be mixed with the nitrous oxide, the variations of the volume of the gas under a given pressure and temperature result perhaps from its whole mass not being homogeneous, as the diminution of the volume is too fast to allow a perfect diffusion of the two gases.

The gas used for these experiments was prepared from pure nitrate of ammonium. The salt was carefully heated in a tin bath in order to prevent any decomposition of the liberated gas by a too irregular heating when directly exposed to a flame. It was washed by transmission through a strong solution of caustic potash and dried over sulphuric acid. The caustic potash decomposes any solid particles of the salt that might be carried over mechanically and retains the nitric acid, whilst the free ammonia is absorbed by the sulphuric acid. Purified in this manner, the gas was made to pass through the glass tube wherein it was to be compressed. A pressure of about 90 to 100 millims. of mercury was required to maintain a moderate current of gas through the capillary bore: this current was continued for five hours or more in order to ensure the complete removal of the air; the capillary end was then sealed and the other end introduced under mercury. As the experiments with the tube filled in this manner indicated always the presence of a permanent gas, I tried afterwards to remove the air by exhausting the tube with the air-pump and then to fill with the gas; this operation was successively repeated from twenty to thirty times, but with no other result.

As I could not get the gas pure by heating nitrate of ammonium, I tried to get it from liquid nitrous oxide as it is made in iron bottles in London; it was probable that the permanent gas would escape first and the nitrous oxide remain pure. This, however, did not occur, and I got nearly the same result as before.

In order to prevent diffusion as much as possible, all the caoutchouc joints were besmeared with a solution of tar and asphalt, and the current of gas issued under sulphuric acid. The amount per cent. of this permanent gas was determined in the following manner:—The absorption-tube of Bunsen's absorptiometer was partly filled under water with nitrous oxide and then left standing three days or longer. The whole of the gas was not absorbed;

there remained a certain quantity, about $\frac{1}{20}$ to $\frac{1}{30}$ of the entire volume, or about 3·5 to 5 per cent.

This permanent gas cannot be nitric oxide nor oxygen; for the current of nitrous oxide being made to pass successively through strong solutions of sulphate of iron and of pyrogallate of potassium, these solutions did not change colour.

The only known permanent gas that could be disengaged is nitrogen. It is a known fact that nitrate of ammonium, in presence of spongy platinum, is decomposed at 160° into nitrogen, nitric acid, and water, the same decomposition of a part of the salt could have been effected by the asperities of the inner surface of the retort. This quantity of nitrogen would exert a considerable influence on the specific gravity of the gas The theoretical specific gravity of pure nitrous oxide is 1·524; but being mixed with nitrogen to an amount of 3·5 to 5 per cent, it should be found much smaller, 1·504 to 1·496 respectively. This result, however, does not accord with actual experiment. The specific gravity of nitrous oxide, prepared from nitrate of ammonium, was determined according to the method of Bunsen ('Gasom. Methoden,' von R. Bunsen), for that purpose I used a balloon of 200 cubic centims. Four experiments gave the following results:—1·531, 1·525, 1·529, and 1·527: the mean value is 1·528, agreeing very well with the theoretical specific gravity of pure nitrous oxide, but giving a difference of 0·024 to 0·032 from the specific gravity that would have been found if the gas had been mixed with nitrogen. These differences are too large to be accounted for by experimental errors.

An analysis of nitrous oxide was made according to a somewhat modified method of Frankland and Ward. The hydrogen used in these experiments was obtained from the electrolytic decomposition of water, and the oxygen was generated by heating mercuric oxide. To ensure that the mercuric oxide is free from nitrogen, it must be prepared by precipitating corrosive sublimate with caustic potash.

Three analyses of air gave the following satisfactory results:—

Nitrogen	79·18	79·15	79·10
Oxygen . . .	20·82	20·85	20·90
	100·00	100·00	100·00

The following are the results of the analysis of nitrous oxide:—

I. *Nitrous oxide obtained from the liquid nitrous oxide of an iron bottle.*

(1)	Volume of nitrous oxide used . . .	117·39
	Volume after the admission of hydrogen . .	263·62
	Volume after explosion . . .	149·12
	Volume after the admission of oxygen ..	206·88
	Volume after explosion	160·19

Hence the volume of the hydrogen 146·23, the volume of the oxygen 57·76, and the contraction after the second explosion 46·69.

The remaining volume (160·19) is a mixture of only nitrogen and oxygen, where the amount of oxygen is $57·76-\frac{1}{3}\times 46·69=42·20$; hence the volume of the remaining nitrogen $160·19-42·20=117·99$. This volume is by 0·6 larger than the volume of the nitrous oxide used; hence the amount per cent. is 0·52.

The amount of hydrogen that remained after the first explosion is $\frac{2}{3}\times$

46·69=31·12; therefore the amount of hydrogen required to combine with the oxygen of the nitrous oxide is 146·23−31·12=115·11; hence the volume of the oxygen contained in the nitrous oxide is equal to $\frac{115 \cdot 11}{2}$=57·55, differing by 1·96 per cent. from the calculated volume of oxygen, which is $\frac{117 \cdot 39}{2}$=58·69.

Hence in 100 volumes of nitrous oxide we find:—

	By experiment	Calculated
Nitrogen ..	100·52	100
Oxygen	49·02	50

(2) Volume of nitrous oxide used	116·93
Volume after the admission of hydrogen .. .	266·20
Volume after explosion	151·69
Volume after the admission of oxygen....	207·19
Volume after explosion	155·71

Hence in 100 volumes of nitrous oxide—

	By experiment.	Calculated.
Nitrogen	100·38	100
Oxygen . ..	49·14	50

(3) Volume of nitrous oxide used	126·42
Volume after the admission of hydrogen ..	284·38
Volume after explosion...	160·55
Volume after the admission of oxygen. . . .	217·53
Volume after explosion....	167·25

Hence in 100 volumes of the gas—

	By experiment	Calculated.
Nitrogen . .	100·49	100
Oxygen	49·22	50

(4) Volume of nitrous oxide used	149·39
Volume after the admission of hydrogen ..	345·92
Volume after explosion...	199·65
Volume after the admission of oxygen .	326·34
Volume after explosion	252·43

Hence in 100 volumes of the gas—

	By experiment	Calculated
Nitrogen	100·06	100
Oxygen	49·28	50

II. *Nitrous oxide obtained by heating nitrate of ammonium.*

(5) Volume of nitrous oxide used	128·20
Volume after the admission of hydrogen	297·06
Volume after explosion......	171·29
Volume after the admission of oxygen	229·80
Volume after explosion.....	166·58

Hence in 100 volumes of the gas—

	By experiment	Calculated
Nitrogen	100·73	100
Oxygen	49·42	50

(6)	Volume of nitrous oxide used	123·33
	Volume after the admission of hydrogen	283·23
	Volume after explosion	162·73
	Volume after the admission of oxygen	223·21
	Volume after explosion	165·09

Hence in 100 volumes of the gas—

	By experiment.	Calculated.
Nitrogen	100·54	100
Oxygen	49·12	50

(7)	Volume of nitrous oxide used	156·81
	Volume after the admission of hydrogen	343·27
	Volume after explosion	190·66
	Volume after the admission of oxygen	265·66
	Volume after explosion	218·80

Hence in 100 volumes of the gas—

	By experiment	Calculated.
Nitrogen	101·66	100
Oxygen	49·49	50

(8)	Volume of nitrous oxide used	147·50
	Volume after the admission of hydrogen	340·10
	Volume after explosion	196·15
	Volume after the admission of oxygen	290·78
	Volume after explosion	220·18

Hence in 100 volumes of the gas—

	By experiment.	Calculated.
Nitrogen	101·05	100
Oxygen	49·32	50

(9)	Volume of nitrous oxide used	165·52
	Volume after the admission of hydrogen	363·19
	Volume after explosion	200·91
	Volume after the admission of oxygen	271·40
	Volume after explosion	221·67

Hence in 100 volumes of the gas—

	By experiment	Calculated.
Nitrogen	101·34	100
Oxygen	49·60	50

(10)	Volume of nitrous oxide used	160·23
	Volume after the admission of hydrogen	357·88
	Volume after explosion	202·91
	Volume after the admission of oxygen	272·54
	Volume after explosion	211·27

Hence in 100 volumes of the gas—

	By experiment.	Calculated
Nitrogen	101·14	100
Oxygen	48·94	50

The only analysis of nitrous oxide I found in Bunsen's 'Gasom. Methoden' is on page 56. Here Quincke gives the results of an analysis of nitric oxide, to which is added a measured quantity of nitrous oxide in order to effect the explosion.

Volume of nitric oxide used . .	20·99
Volume after the admission of nitrous oxide	102·44
Volume after the admission of hydrogen ..	233·90
Volume after explosion	123·10
Volume after the admission of oxygen .	167·62
Volume after explosion .	122·08

Hence we find, on the supposition that the nitrous oxide is pure, the amount of nitrogen and oxygen in the nitric oxide in 100 volumes —

	By experiment	Calculated
Nitrogen......	52	50
Oxygen . ..	47	50
	99	100

But, on the supposition that the nitric oxide is pure, this analysis gives results according with my own

In 100 volumes of nitrous oxide we find—

	By experiment	Calculated
Nitrogen	100·98	100
Oxygen	49·18	50

The general result of these analyses is —

(1) The volume of the oxygen in the nitrous oxide is smaller than the volume of the nitrous oxide used by 0·61 to 2·13 per cent.

(2) The volume of the nitrogen is larger than the volume of the nitrous oxide used by 0·38 to 1·66 per cent.

That the volume of the oxygen is smaller than half the volume of the nitrous oxide used can be explained by the presence of a certain quantity of nitrogen, ranging from 0·61 to 2·13 per cent, a quantity much smaller than the total amount of nitrogen mixed with the nitrous oxide, which was found to be between 3·5 and 5 per cent.

That the volume of the nitrogen contained in the nitrous oxide is larger than the volume of the nitrous oxide used could be explained by the presence of a gas containing more nitrogen in a molecule than nitrous oxide, for instance N_3O; such a gas, however, is not known.

It will be observed that these analyses do not agree among themselves very nearly; and having been prevented from making more experiments, I will not venture to draw any conclusions from these results, as more analyses should be made, chiefly because the apparatus with which they were performed was somewhat defective with regard to the diameter of the glass tubing connecting the absorbing with the measuring tube.

Faraday was the first who observed an anomaly with nitrous oxide; his results were very uncertain as to the pressure of its saturated vapour. At a temperature of 0° F. this pressure amounted to 19·05 atmospheres when working from lower to higher temperatures; but after waiting a day he found 24·40 atmospheres, consequently a difference of 5·35 atmospheres. This discrepancy he ascribed to the gas being a mixture of two different bodies soluble in each other but differing in the elasticity of their vapour.

Stefan (Sitzungsber der K. Akademie der Wissenschaften zu Wien, Bd. lxxii. 1875), in his researches on heat-conduction of gases, also found the nitrous oxide mixed with another gas. He says, "Von diesem Gase wurde vor dem Abschlusse der Durchleitung durch den Apparat eine Probe in einer Absorptionsröhr über Wasser aufgefangen. Nach zwei Tagen war das Gas bis auf einen etwas über 10 Procent des ursprünglichen Volumens betragenden Rückstand (Stickstoff) verschwunden."

Eighth Report of the Committee on the Treatment and Utilization of Sewage, reappointed at Bristol, 1875, *and consisting of* RICHARD B. GRANTHAM (Chairman), *C.E., F.G.S.*, Professor A. W. WILLIAMSON, *F.R.S.*, Dr. GILBERT, *F.R.S.*, Professor CORFIELD, *M.A., M.D.*, WILLIAM HOPE, *V.C.*, F. J. BRAMWELL, *C.E., F.R.S., and* J. WOLFE BARRY, *C.E.*

YOUR Committee have during the past year, ending 24th March, 1876, been able to conduct more complete observations at Breton's Farm, near Romford, and have been also able to test experimentally the value of last year's observations by having analyses made of samples of sewage and effluent water kept under various conditions. The expense attending this year's experiments has been generously borne by a Member of the Association.

From Table I. it appears that the quantity of sewage received from the town was greater than in any year during the period over which the Committee's observations extend, not excepting the year 1872–73, when the rainfall was larger by 3 inches than this year; it is therefore clear that the quantity of sewage proper received from the town has increased steadily year by year, thus:—

Year.	Sewage	Rainfall
	tons	inches
1870-71 June 12 to July 15. (399 days).	383,926	22·64
1871-72. March 25 to March 24	416,787	21·56
1872-73. March to March	479,942	29·89
1873-74 March to March	not gauged	not gauged
1874-75. March to March	482,335	19·79
1875-76. March to March	546,982	26·75

It should be observed again that, as stated in last year's Report, it has not been possible during the past two years to gauge the sewage directly in the distributing-trough, and so the amount is calculated as follows:—the "day" sewage from gaugings taken in the sewers during the working hours of the engine, and the "night" sewage from the difference in the contents of the tanks at the times of stopping and starting the engines night and morning.

It is worthy of note that while the weekly average of the noonday atmospheric temperatures varied from 31° to 79° Fahr., the average temperatures of the sewage only varied from 55° to 70° Fahr.

Table II. is given again after a lapse of two years, during which it was impossible for want of funds to have a sufficient number of analyses made.

It appears that during the months of June, July, August, and September little or no nitrogen as nitrates or nitrites was found in the effluent water; and from this it might hastily be concluded that for some reason or another the usual amount of oxidation had not gone on in the soil; but the fact turns out to be that oxalic acid had been added to the samples (both sewage and effluent water) of these months with the view of preventing oxidation going on in them during and after collection, and this prevented the estimation of nitrogen in these forms by the process used.

To test this some experiments were made as follows:—The October effluents, to which no oxalic acid had been added, gave 0·49 of nitrogen as nitrates or nitrites per 100,000 parts; to 500 cubic centimetres of this effluent 0·5 grain of oxalic acid was added, and the mixture allowed to stand for five days; no nitrites could then be discovered in it. Again, the effluent water collected at Breton's during June 1876 was examined as follows:—"One portion of it was analyzed, taking the sample from the full bottle; at the same time another portion was poured off into a bottle, filling this bottle quite full, and to this portion 18 grains of solid oxalic acid was added and this allowed to stand for seven clear days, then analyzed. It was kept in a cool cellar. The 18 grains of oxalic acid to the quantity taken is in the proportion of 2 oz. to the carboy of 12 gallons.

Analyses.

	Without Oxalic Acid.	With Oxalic Acid.
Nitrogen as Ammonia ..	0·004	0·006
Nitrogen as Nitrates	0·889	0·000
Nitrogen not Nitrates ...	0·137	0·127
Chlorine	9·30	9·50

(There is no doubt that the process of analysis accounts for the total disappearance of the nitrates.)"—Dr Russell.

The "total nitrogen" in the effluent waters for those four months is therefore represented in the Table as less than it should be. Leaving out those four months, the "total nitrogen" in the effluent waters is, however, higher than it was during the preceding year, this being chiefly due to an increased amount of "nitrogen as nitrates," the amount of nitrogen "not nitrates" being very low throughout the year except in the month of June.

Table III. is also given again in its original form, except that the effluent water has only been *gauged* when it was mixed with the sewage, although in collecting the samples for analyses portions were taken from all the effluent-water drains; and it is the results of the analyses of these mixed samples that are used in calculating the amount of nitrogen in the effluent water returned to the tanks.

From this Table it appears that the true average amount of nitrogen in the sewage was 5·53 parts per 100,000, and that the amount of nitrogen calculated to be applied to the farm in the sewage was 30·2525 tons; of this quantity 0·1406 ton was collected in the effluent water repumped over the farm.

It is remarkable how little the true average composition of the sewage differs from the results obtained in previous years; and the Committee consider that this circumstance affords considerable proof of the accuracy of their methods of sampling, the principle of which has always been that the samples should be taken in proportion to the amount of flow at the time; thus the amount of nitrogen in parts per 100,000 in the sewage has been, according to the calculations from the results of the gaugings and analyses, as follows:—

1871-72	5·529
1872-73	5·151
1873-74.	not taken.
1874-75.	5·56
1875-76.	5·53

With regard to these figures your Committee would observe that the rainfall in the year 1872-73 was excessive, and this no doubt accounts for the sewage containing a smaller proportion of nitrogen in that year; and that with regard to the year 1874-75, the number given was the result of a single analysis of a mixture made of all the monthly samples taken in quantities proportionate to the amounts of sewage distributed each month.

The Committee have thought it desirable to make some observations on the changes which occur in sewage and effluent water when kept for some time, with the view of ascertaining how far this result for 1874-75 is reliable.

Bottles were filled with portions of the samples of sewage and of effluent water collected during November 1875, and put aside in a cool cellar; they were analyzed in May 1876, and the results of these analyses compared with the previous ones of the same samples were as follows:—

Description of Sample.	Chlorine.	Nitrogen.		
		As Ammonia.	As Nitrates and Nitrites.	Total in solution and suspension.
Sewage, Nov. 1875.				
1st Analysis, December 1875 ..	12·5	3·33	.... .	5·58
2nd Analysis, May 1876	12·4	3·95	......	5·60
Effluent water, Nov. 1875.				
1st Analysis, December 1875 ...	11·0	0·224	0·76	1·10
2nd Analysis, May 1876	11·0	0·002	1·02	1·09

This shows that the total amount of nitrogen in the solid matter contained in a sample of sewage or of effluent water is not altered by keeping, provided the bottle be well filled. It is worthy of note that the nitrogen in the effluent water was almost all converted into nitrates*.

In order to ascertain the effect of keeping sewage in unfilled bottles, the following experiments were made. The remnants of the January sewage and effluent water, which had been left in the bottles, were analyzed again on July 15th, 1876, and the sewage again on July 31st, and the following results obtained:—

Description of Sample	Chlorine.	Nitrogen.		
		As Ammonia	As Nitrates and Nitrites.	Total in solution and suspension.
Sewage, Jan. 1876				
1st Analysis, February 1876	14·1	2·58	. .	6·48
2nd Analysis, July 15th, 1876	13·9	1·34		2·64
3rd Analysis, July 31st, 1876		0·025	1·05	1·52
Effluent water, Jan. 1876				
1st Analysis, February 1876	10·0	0·174	0·87	1·28
2nd Analysis, July 15th, 1876	10·0	0·005	1·14	1·22

It appears, then, that a large quantity of the nitrogen in the sewage was lost between February 1876 and July 15th, 1876, while the nitrogen in the effluent water was only slightly diminished in amount, but was almost all oxidized to the condition of nitrates.

It appeared desirable to ascertain how much of the nitrogen in the sewage was thus oxidized, and a third analysis was therefore made on July 31st, 1876, which showed that a still further loss of nitrogen had taken place, so that the total nitrogen which was at first 6·48 parts had been actually reduced to only 1·52 part per 100,000; and of this 1·52 no less than 1·05 part was in the form of nitrates. It is probable that much of the nitrogen thus lost escaped in the free state.

The total amount of nitrogen received from the town in the sewage was greater than during any previous year, and shows conclusively that the increased amount of sewage does not merely depend on the rainfall, which was considerable, but that new connexions with the sewers are being made in the town from time to time. The calculated amounts for the past years are as follows:—

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* The unusually small amount of nitrogen "not nitrates" in the effluent waters in 1874–75 was doubtless partly owing to the fact that the samples were not analysed until the end of the year.

Year	Nitrogen
	lbs.
1871-72	7 209*
1872-73	27,116
1873-74	No analyses made
1874-75	28 38
1875-76	30 2525

The figure for 1874-75 is of course obtained by using the result of the one analysis made that year. From these figures we see that the amounts of nitrogen delivered on to the farm in the sewage were approximately the same during the first two years of the observations, and that they have increased during the last two.

Table IV. gives as usual a detailed account of the crops grown, and the facts relating thereto are summarized in Tables V. and VI.

From Table V. it will be seen that the total produce of the farm was under 2115 tons, or less than last year, and less than the average of the last four years, which was 2232 tons; and the main reason of this is the considerable increase in the acreage of cereals and of pulse grown, thus:—

	1871-72		1872-73		1873-74		1874-75		1875-76	
	acres	tons	acres	tons	acres	tons	acres	tons	acres	tons
Pulse	2·33	2·59	12·53	33·0	4·97	4·29	2·78	8·45	23·04	46·46
Cereals	·90	3·00	26·18	86·1	38·82	84·25	38·13	2·68	26·79	74·96
	3·23	5·59	38·71	119·1	43·79	88·54	40·91	81·13	49·83	121·42

About Table VI. the same remark must be made as was made last year, viz. that the acreage of Italian rye grass includes the spring sowings as well as the regular crops, and this accounts for the small average produce per acre of that crop; the three regular plots of this crop yielded respectively 58, 53, and 48 tons per acre.

The mangold crops were also very fine and gave the highest total tonnage per acre yet recorded for those roots, viz. very nearly 47 tons per acre.

The nitrogen recovered in the crops was 20 558 lbs., a somewhat larger amount than last year; this is equivalent to 30·34 per cent. of that received in the sewage.

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* This is not the amount *utilized* as given in the Report for 1871-72, but the amount *received* as shown in the Report for 1872-73.

The Table shows that 139 lbs. of nitrogen were recovered per acre over the aggregate acreage under crop during the year, viz. 147·87 acres; it will, however, be more correct and of greater practical utility to show the amount of nitrogen recovered in the crops per acre of the farm under crop, viz. 108 44 acres, during the past five years.

In the following Table the amount of nitrogen applied to the farm in the sewage and that recovered in the crops is shown for each of the last five years; and it appears that the amount of nitrogen recovered in the crops during the whole period is equal to 32 88 per cent. of the amount applied in the sewage, and that the amount recovered per acre of the farm under crop averaged 182 lbs.

Year	Sewage	Nitrogen.			
		In Sewage.	In Crop.	Percentage recovered in Crops	Recovered per acre of Farm.
	tons	lbs.	lbs		lbs.
1871 72	380,227	47,095	19,667	41 76	181
1872–73	523,810	60,438	15,704	26 00	145
1873–74	.	61,924*	22,766	36 74	210
1874–75.	509,139	63,410	20,166	31·80	186
1875–76	546,982	67,765	20,558	30·34	189
		300,632	98,861	32·88	182

It will be observed that the small amount of nitrogen recovered per acre during the year 1872–73 was compensated for by the unusually large amount recovered in 1873–74, which latter was due to the fact that certain crops taken off the ground in 1873–74 had derived the greater part of their nitrogen from the sewage of the previous year.

The value of these results is much enlarged by the fact that they have been obtained by a series of observations and experiments extending over a period of five years, so that the effect of the inevitable annual variations, of which a notable example is furnished by the first three years, is got rid of.

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* As the sewage was not gauged in the year 1873–74, the amount of nitrogen applied is taken as the mean of that applied in the years 1872–73 and 1874–75.

TABLE I.—*Breton's Sewage-Farm.*

Statement of Weekly Quantities of Sewage received on the Farm from the Town of Romford, from March 25, 1875, to March 24, 1876.

No of weekly return	Dates (inclusive).	Average noonday temperature	Rainfall during week	Sewage delivered on farm.	Average temperature thereof
		° F	in	gallons	° F
251.	1875 March 25 to March 28	54	0 10	1,061 000	55
252	,, ,, 29 , April 4	52	0 07	1,970,000	56
253	,, April 5 , , 11	52	0 82	2,429,000	59
254	,, ,, 12 18	50	0 00	2,025,000	62
255	,, ,, 19 , , 25	57	0 33	1,783,000	63
256	, , 26 , May 2	64	0 57	2,051,000	63
257	,, May 3 , ,, 9	62	0 38	2,173,000	63
258	,, , 10 , , 16	69	0 00	1,803,000	64
259	,, , 17 , , 23	62	0 34	2,147,000	65
260	,, ,, 24 ,, 30	64	0 21	2,135,000	65
261	,, 31 , June 6	71	0 00	1,959 000	66
262	,, June 7 ,, ,, 13	64	0 94	2,078,000	67
263.	,, 14 , , 20	64	0 37	2,036 000	66
264	, , 21 , 27	66	0 02	1,951,000	69
265.	,, , 28 ,, July 4	66	1 44	2,723,000	66
266	July 5 ,, 11	67	0 41	1,937 000	69
267	,, ,, 12 ,, 18	61	2 63	2,898,000	63
268	,, , 19 , , 25	6[illegible]	1 16	2,626,000	63
269	,, , 26 Aug 1	71	0 09	2 005 000	66
270	, Aug 2 8	72	0 00	1,839,000	69
271	, , 9 , 15	74	0 20	1,981,000	69
272	, 16 ,, , 22	79	0 38	2,388,000	68
273	, 23 , , 29	69	0 45	2,081,000	68
274	, , 30 Sept 5	65	0 12	2,069,000	67
275	, Sept 6 , , 12	71	0 11	2,083,000	70
276.	,, ,, 13 ,, ,, 19	69	0 00	2,242,000	68
277.	,, ,, 20 , ,, 26	63	1 98	3,121,000	69
278.	,, , 27 ,, Oct 3	62	1 09	2,433,000	66
279.	,, Oct 4 ,, 10	60	0 08	2,315,000	64
280	, ,, 11 ,, , 17	54	0 37	2,087,000	64
281	,, , 18 , 24	53	2 35	3 662 000	66
282.	, , 25 , , 31	45	0 17	2,709,000	60
283	,, Nov 1 , Nov 7	51	0 72	2,513,000	61
284	,, , 8 , ,, 14	44	2 31	2,955,000	62
285.	,, ,, 15 , ,, 21	49	0 22	2,688,000	61
286	,, ,, 22 ,, 28	36	0 07	2,510,000	57
287	,, ,, 29 , Dec 5	33	0 40	2,260 000	57
288	,, Dec 6 ,, 12	37	0 20	2,551,000	57
289.	,, , 13 , , 19	40	0 00	2 420,000	58
290.	,, 20 ,, 26	48	0 31	2,439 000	57
291.	,, , 27 , Jan 2 1876	45	0 13	2,484,000	57
292	1876 Jan 3 ,, ,, 9	37	0 21	2,752,000	59
293.	,, ,, 10 , ,, 16	31	0 09	1,803,000	57
294.	, , 17 , ,, 23	43	0 31	2 414,000	59
295	,, ,, 24 ,, , 30	46	0 03	2,150,000	60
296	,, , 31 ,, Feb 6	44	0 37	2,587,000	60
297.	,, Feb 7 ,, ,, 13	35	0 00	2 145,000	58
298	, ,, 14 , ,, 20	50	0 64	2,464,000	59
299.	,, ,, 21 ,, ,, 27	49	0 65	2,685,000	59
300.	,, ,, 28 ,, March 5	50	0 79	2,640,000	60
301.	, March 6 , ,, 12	47	0 95	2,857,000	60
302	, , 13 ,, ,, 19	43	0 89	2,572,000	58
303	, , 20 ,, ,, 24	46	0 28	1,835,000	58
		Total	26 75		
			Total	122,524,000	
			Tons	546,982	

Table II.—*Breton's Sewage Farm*

Statement showing Results of Monthly Analysis of Sewage as pumped and of Effluent Drainage water from March 1875 to March 1876

Results given in parts per 100 000

Month	Sewage as pumped			Effluent drainage water				
	Ammonia	Chlorine	Total Nitrogen in solution and suspension	Ammonia	Chlorine	Nitrogen as Nitrates and Nitrites	Nitrogen not as Nitrates	Total Nitrogen
1875								
April	3·90	12·30	5·02	0·005	11·40	0·37	0·23	0·60
May	4·95	12·10	5·58	0·002	11·00	0·44	0·22	0·66
June*	58	11 0	4·46	0·333	11 4	none	0·95	0·95
July*	80	12·00	8·18	0·568	10·30	0·05	0·37	0·42
August*	66	12·40	4·18	0·15	11·20	none	0·41	0·41
September*	2·69	11·36	4·32	0·125	11·00	trace	0·24	0·24
October	4·07	10·90	4·47	0·025	10·00	0·49	0·15	0·64
November	3·33	1 50	5·58	0·224	11·00	0 6	0·34	1·10
December	2·30	9·60	5·27	0·004	8·75	0·76	0·06	0·82
1876								
January	2·58	14·10	6·48	0·21	10·00	0·87	0·41	1·28
February	3·44	9·70	5·93	0·178	9·40	1·07	0·23	1·30
March	3·64	10·20	6·29	0·008	9·10	0·73	0·09	0·82

* Oxalic acid had been added to these samples

TABLE III —*Breton's Sewage-Farm*

Statement showing the Monthly Quantities of Sewage and Effluent Water distributed on the Farm, and the Nitrogen contained therein from March 25, 1875 to March 24, 1876

Dates (inclusive)	Sewage			Effluent Water		
	Quantity	Nitrogen per 100 000 tons	Total Nitrogen	Quantity	Nitrogen per 100 000 tons	Total Nitrogen
1875	tons	tons	tons	tons	tons	tons
Mar 25 to Mar 31	8 500	*5 02	4267			
April 1 April 30	39 147	5 02	1 9652	1 375	0 60	0 0082
May 1 May 31	40 946	5 98	2 4486	4 113	0 66	0 0271
June 1 June 30	39 518	4 46	1 7625	[illegible] 263	0 95	0 0215
July 1 July 31	49 52	8 18	4 0509			
Aug 1 Aug 31	39 393	4 18	1 6466	4 772	0 41	0 0196
Sept 1 Sept 30	45 857	4 32	1 [illegible]	6 897	0 24	0 0166
Oct 1 Oct 31	53 187	4 47	2 37 5			
Nov 1 Nov 30	50 594	5 58	8331			
Dec 1 Dec 31	48 170	5 27	2 5386			
1876 Jan 1 to Jan 31	45 161	6 48	2 9264	2 536	1 28	0 0325
Feb 1 Feb 29	46 130	5 93	2 7355	625	1 30	0 0081
Mar 1 Mar 24	40 857	6 29	2 5699	848	0 82	0·0070
	546 982	5 53	30 2525	23,429		0 1406

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* There being no analyses for March 1875 the April composition has been adopted for that month

TABLE IV —*Breton's*

Statement showing Crops grown from

Plot.	No of beds (inclusive)	Acreage	Crop	Date when sown or planted
A	1 to 29 1 20 21 29	9 80 6 41 3 39	Mangold Cabbage Fallow	Apr l 1875 Nov 1875
Total A		9 8		
B	1 to 26	12 12 12 12	Barley Italian rye grass	March 1875
Total B		12 12		
C	All Part	1 97 50 1 47	Oats Cabbage Fallow	March 1875 Oct 1875
Total C		1 97		
D	All. 12 13 to 18 19 22 1 22	6 93 31 1 89 1 26 6 93	Cabbage Kohl rabi Hardy green plants Sprouting broccoli Italian rye grass	Oct and Nov 1874 Apr l 1875 May 1875 Apr l 1875 Oct 1875
Total D		6 93		
E	1 to 22	5 76	Italian rye grass	Sept 1874
F	1 to 14&17&18 15 16 1 to 5 6 to 9&14 to 16 All.	3 39 42 1 06 1 48 3 82	Cabbage Spinach Hardy greens Cabbage plants Wheat	Oct 1874 Apr l 1875 June 1875 July 1875 Feb 1876
Total F		3 82		
G	1 to 22	5 17	Italian rye grass	Sept 1874

Sewage-Farm.

March 25, 1875, to March 24, 1876.

Date when cut or gathered.	Produce.		Remarks.
	Total.	Per acre.	
	tons.	tons.	
Oct. and Nov. 1875 .	469 41	47 9	One eleventh of crop ploughed in.
. . .	.	. ...	Crop remained March 1876.
. ..	469 41	47 9	Part of plot under crop at end of year.
Aug. 1875	32 16	2 7	Including 20·83 tons straw
Oct. 1875	18 16	1·5	Sown with Barley. One cutting only. The crop remained March 1876.
..	50·32	4·2	Plot all under Grass at end of year.
Aug. 1875 . . .	6 05	3 1	Including 3·47 tons straw.
March 1876	1 71	3 4	
....	7·76	3 9	Plot all fallow at end of year.
April to Sept 1875 ..	79·41	11·5	
Sept. 1875	1 31	4 2	
July and Aug. 1875 ...	16 40	8·7	
Sept. 1875	12 44	9·9	
.. ..	......	......	Crop remains.
....	109 56	15 8	Plot under Grass at end of year.
April to Nov. 1875 .	333 72	57·9	Seven cuttings. Plot fallow at end of year.
April to Sept. 1875 ...	41 59	12 3	
July 1875	1·25	3·0	
Sept. and Oct. 1875 ..	19 68	18 6	
Nov. 1875	2 41	1 6	
....	. ....	......	Wheat remains. Rye-grass sown May 1876.
....	64 93	17 0	Plot under Wheat at end of year.
April to Nov. 1875 ...	250·56	48·5	Seven cuttings. Plot fallow at end of year.

TABLE IV.

Plot	No of beds (inclusive)	Acreage	Crop	Date when sown or planted.
H	1 to 24	6 40	Italian rye grass .	June 1874 . . .
I	1 to 18	6 67	Barley ..	March 1875 . . ..
"	"	6 67	Turnips	Aug 1875 .
Total I	.. ..	6 67	...	. .
K	1 to 3	1 19	Walcheren cauliflowers .	June 1875 ....
"	4 & 5	82	Spinach	March 1875
"	4 to 8	2 56	Cabbage	June and Aug. 1875
"	6 & 7	82	Hardy green plants ..	April 1875 . ...
"	8 " 9	83	Savoy plants	" " .
"	10	40	Cabbage & Brus sprouts	" "
"	11	38	Walcheren cauliflowers	" "
"	1 to 11	4 44	Wheat	Feb 1876 ..
Total K	. . .	4 44	... . .	. ... . .
L	1 to 20	2 87	Beans	March 1875
M	1 to 12	2 89	Peas	March 1875 . .
"	13	28	Sprouting broccoli plants	April 1875 ..... .
"	1 to 9	2 33	Kohl rabi .. .	Aug and Sept. 1875
"	13	28	Sprouting broccoli ..	Sept 1875 ....
"	1 to 13	3 17	Wheat	Feb 1876 . .
Total M	....	3 17	.. . .	....
N	1 to 16	4 15	Mangold	April 1875 . ..
O	All	5·92	Carrots . . .	April 1875 ....
"	"	5 92	Peas .	March 1876.
Total O	.. .	5 92	... . .	.. . .
P	All	3 50	Oats	March 1875 .. . .
"	"	3·50	Sprouting broccoli	Sept. 1875 . ... ..
Total P		3 50	. .. .	.. . .

(*continued*).

Date when cut or gathered.	Produce.		Remarks.
	Total.	Per acre	
	tons	tons	
Apr. 1875 to Mar 1876	341 48	53 4	Five cuttings. Plot fallow at end of year
Aug 1875 . .	18 71	2 8	Including 11 5 tons straw.
March 1876	16 06	2 4	
....	34 77	5 2	Plot fallow at end of year
Aug. and Sept 1875	5 24	4·4	
June 1875 ...	2 00	2 4	
Sept. 1875 to Feb 1876	24 42	9 5	
July and Aug 1875	7·19	8 8	
July 1875	7 57	9 1	
Nov. and Dec. 1875 .	4 40	11 0	
June 1875	1 68	4 4	
.. .. .	. ..		Wheat remains
... .	52 50	11 8	Plot all under Wheat at end of year.
Sept 1875	5 42	1 9	Straw 3 76 tons included. Plot fallow at end of year.
July 1875	5 87	2 0	Including 4 22 tons straw
Sept. 1875	80	2·9	
Nov and Dec. 1875 ..	15 60	6 7	
Feb. 1876 .	·40	1 4	
....	..	... .	Wheat remains.
.. ..	22 67	7 2	Plot all under Wheat at end of year
Nov 1875	184 90	44 6	Plot fallow at end of year
Nov 1875	80 80	13 6	
.. .	80 80	13·6	Plot in crop at end of year
Aug 1875	9 82	2 8	Including 6 9 tons straw.
March 1876	5 54	1 6	
....	15 36	4 4	Plot fallow at end of year

TABLE IV

Plot.	No of beds (inclusive)	Acreage	Crop	Date when sown or planted
Q	All	2 34	Beans	March 1875
R	Part.	2 40 12	Beans Oziers	March 1875
Total R		2 52		
S		22	Rhubarb	Feb 1873
U	All	2 53 2 53	Oats Sprouting broccoli	March 1875 Sept 1875
Total U		2 53		
V	All	5 93	Beans	March 1875
W	All	2 75 2 75	Peas Sprouting broccoli	March 1875 Sept 1875
Total W		2 75		
X	All	3 86	Beans	March 1875
Y	All.	3 60	Hay	Permanent grass
Various		0 20	Oziers	Permanent

(continued).

Date when cut or gathered.	Produce.		Remarks.
	Total	Per acre	
	tons.	tons.	
Sept. 1875	5·18	2·2	Including 3·76 tons straw. Plot fallow at end of year.
Sept. 1875	5·23 1·90	2·2 15·8	Including 3·76 tons straw. Oziers remain.
.. ..	7·13	2·8	Plot nearly all fallow at end of year.
March 1876	0·71	3·2	Rhubarb remains.
Aug 1875 ..... . March 1876	8·22 6·85	3·2 2·7	Including 5·78 tons straw.
. ...	15·07	5·9	Plot fallow at end of year.
Sept. 1875	11·88	2·0	Including 8·10 tons straw. Plot fallow at end of year.
June & July 1875 . March 1876	5·09 10·52	1·9 3·8	Including 3·70 tons straw.
.. ..	15·61	5·7	Plot fallow at end of year.
Sept. 1875	7·44	1·9	5·20 tons straw. Plot fallow at end of year.
June and Sept. 1875 ...	23·80	4·2	Two crops. Grass remains.
....	3·7	18·5	

TABLE V.—*Breton's Sewage-Farm.*

Season 1875–76.—Summary of Cropping Return.

Plot.	Acreage	Crops.	Produce.	
			Total	Per acre.
			tons.	tons
A	9·80	Mangold and cabbage ..	469·41	47·9
B	12·12	Barley and Italian rye-grass	50·32	4·2
C	1·97	Oats and cabbage	7·76	3·9
D	6·93	Cabbage, kohl rabi, hardy greens, sprouting broccoli.	109·56	15·8
E	* 5·76	Italian rye-grass	333·72	57·9
F	3·82	Cabbage, spinach, hardy greens, and cabbage-plants.	64·93	17·0
G	* 5·17	Italian rye-grass	250·56	48·5
H	* 6·40	Italian rye-grass	341·48	53·4
I	6·67	Barley and turnips	34·77	5·2
K	4·44	Cauliflowers, spinach, cabbage, hardy green plants, savoy, Brussels sprouts.	52·50	11·8
L	2·87	Beans	5·42	1·9
M	3·17	Peas, sprouting broccoli plants, and kohl rabi.	22·67	7·2
N	4·15	Mangold	184·90	44·6
O	5·92	Carrots	80·80	13·6
P	3·50	Oats and sprouting broccoli	15·36	4·4
Q	2·34	Beans	5·18	2·2
R	2·52	Beans and oziers	7·13	2·8
S	0·22	Rhubarb	0·71	3·2
U	2·53	Oats and sprouting broccoli . .	15·07	5·9
V	5·93	Beans	11·88	2·0
W	2·75	Peas and sprouting broccoli	15·61	5·7
X	3·86	Beans	7·44	1·9
Y	5·60	Hay	23·80	4·2
various	0·20	Oziers	3·70	18·5
	108·64	Total	2114·68	19·5

* See Note at foot of Table VI.

TABLE VI —*Breton's Sewage-Farm*

Summary of Crops gathered from March 25, 1875, to March 24, 1876, showing the quantity of each kind of Produce and Nitrogen contained therein

Crop	Total acreage of each description of crop	Produce of each crop		Total Nitrogen estimated to be in crops		
		Total	Per acre	Per cent	Total	Per acre
	acres	tons	tons		lbs	lbs
Italian rye grass	*29 45	943 92	32 1	0 54	11,418	388
Hay	5 60	23 80	4 2	2 00	1,066	190
Oziers	0 32	5 60	17 5		63	196
Cabbage	14 86	149 54	10 1	0 25	837	56
Hardy greens	3 77	43 27	11 5	0 25	242	64
Savoys	0 83	7 57	9 1	0 25	42	51
Brussels sprouts & cabbage	0 40	4 40	11 0	0 25	25	62
Broccoli	10 60	36 55	3 4	0 25	205	19
Spinach	1 24	3 25	2 6	0 25	18	15
Kohl Rabi	2 64	16 91	6 4	0 375	142	54
Cauliflowers	1 57	6 92	4 4	0 25	39	25
Beans	17 40	35 15	2 0	0 50	394	23
Peas	5 64	peas 3 04 straw 7 92	0 5 1 4	3 40 0 80	232 142	66
Carrots	5 92	80 80	13 6	0 20	362	61
Turnips	6 67	16 06	2 4	0 18	65	10
Mangold	13 95	654 31	46 9	0 25	3,664	263
Oats	8 00	grain 7 94 straw 16 15	1 0 2 0	2 00 0 60	355 217	72
Barley	18 79	grain 18 54 straw 32 33	1 0 1 7	1 60 0 50	665 362	55
Rhubarb	0 22	0 71	3 2	0 2	3	14
	147 87	2114 68	14 3		20 558	139

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* This acreage of Italian rye grass includes not only the 17 33 acres of plots E, G, and H (marked * in Table V), but also the 12 12 acres of plot B, which were sown, according to the usual practice for the following year's use and from which only one very light cutting was taken

TABLE VII —*Breton's Sewage-Farm*

Statement of Land in crop and Land lying fallow on March 24, 1876

Plot	Acreage	Area in crop	Area fallow
	acres	acres	acres
A	9 80	6 41	3 39
B	12 12	12 12	
C	1 97		1 97
D	6 93	6 93	
E	5 76		5 76
F	3 82	3 82	
G	5 17		5 17
H	6 40		6 40
I	6 67		6 67
K	4 44	4 44	
L	2 87		2 87
M	3 17	3 17	
N	4 15		4 15
O	5 92	5 92	
P	3 50		3 50
Q	2 34		2 34
R	2 52	12	2 40
S	22	22	
U	2 53		2 53
V	5 93		5 93
W	2 75		2 75
X	3 86		3 86
Y	5 60	5 60	
	108 44	48 75	59 69

Comparison

		In crop	Fallow	Total
		acres	acres	acres
March 24	1872	40 49	63 39	103 88
	1873	87 62	19 93	107 55
	1874	89 09	19 35	108 44
	1875	79 40	29 04	108 44
	1876	48 75*	59 69	108 44

* Including (as pointed out in previous Reports) spring sowings amounting this year to about 17 acres

Improved Investigations on the Flow of Water through Orifices, with Objections to the modes of treatment commonly adopted. By Prof. JAMES THOMSON, *LL.D., D.Sc.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

THE methods usually put forward for treating of the flow of water out of vessels by orifices in thin plates, slightly varied though they may be in different cases, are ordinarily founded on assumptions largely alike in these different cases, and largely erroneous. The theoretical views so arrived at, and very generally promulgated, are in reality only utterly false theories based on suppositions of the flow of the water taking place in ways which are kinematically and dynamically impossible, and are at variance with observed facts of the flow, and even at variance with the facts as put forward by the advancers themselves of those theories. The admittedly *erroneous results* brought out through those fallacious "theories," and commonly miscalled "*theoretical results*," are afterwards considerably amended by the introduction into the formulas so obtained of constant or variable coefficients, or otherwise, so as to be brought into some tolerable agreement with experimental results. These means of practical amendment, however, being themselves not established on any scientific principles, can at best only conduce to the attainment of useful empirical formulas, but cannot, by their application to the originally false theoretical views, come to develop any true scientific theory. A theory may, no doubt, be regarded as a good scientific theory, and as being good for practical purposes, which leaves out of account some minor features or conditions of the actual facts. In so far as it leaves any influential elements out of account, it is imperfect; but if the conditions which, for simplicity, or from want of complete knowledge of the subject, or for any other reason, are left out be of very slight influence on the practical results in question, the theory may be regarded as a very good one, though not quite perfect. In the case, however, of the hydraulic theories now referred to, the false principles involved in the reasonings relate to the main and important conditions of the flow, and not to any mere minor considerations, the imperfections or errors of which might be of but slight importance in the development of the main principles involved, and but little influential on the results sought to be attained.

I will now proceed to give some examples or sketches of the usual methods of treating the subject.

I will first take the case of water flowing from a state of rest through an orifice in a vertical plane face. This case is ordinarily treated by supposing the orifice to be divided into an infinite number of infinitely narrow horizontal bands of area, and supposing the velocity of the water in each band to be that due, through the action of gravity, to a fall from the still-water surface-level down to that band; then multiplying that velocity by the area of the band, and treating the product as being the volume flowing per unit of time across that horizontal band or element of the area; and integrating to find the sum of all these volumes of water for all the bands, and treating this sum as being the "theoretical" volume per unit of time flowing across the whole area of the orifice. This result is commonly called the "*theoretical discharge*" per unit of time; but, as it is known not to be the actual discharge, it is then multiplied by a numerical coefficient called by some "*the* *coefficient of contraction,* and by others the '*coefficient of discharge,*' in order to find the actual discharge per unit of time.

Thus for the case of a rectangular orifice in a vertical plane face as in fig. 1—where W L is the level of the still-water surface, and A B C D is the

Fig. 1

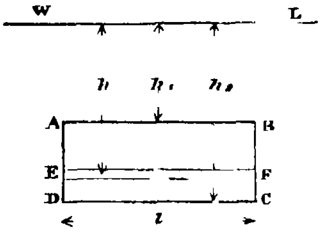
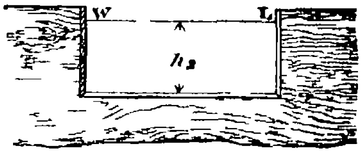


Fig. 2



orifice, with two edges A B and C D level and E F is an infinitely narrow horizontal band extending across the orifice at a depth h below the still-water surface-level and having dh as its breadth vertically measured, while it has l, the horizontal length of the orifice as its length, and where, as shown in the figure the depths of the top and bottom of the orifice below W L are denoted by h_1 and h_2 respectively—if q is put to denote the so-called "theoretical" volume per unit of time, and Q the actual volume per unit of time, it is commonly stated that

$$dq = \sqrt{2gh}\; l\,dh,$$

whence

$$q = \int_{h_1}^{h_2} \sqrt{2gh}\; l\,dh = l\sqrt{2g}\int_{h_1}^{h_2} h^{\frac{1}{2}}dh,$$

or

$$q = \tfrac{2}{3} l\sqrt{2g}\left(h_2^{\frac{3}{2}} - h_1^{\frac{3}{2}}\right)$$

and then when c is put to denote the so-called "*coefficient of contraction,*" it is stated that the actual quantity flowing per unit of time is

$$Q = \tfrac{2}{3} c l\sqrt{2g}\left(h_2^{\frac{3}{2}} - h_1^{\frac{3}{2}}\right) \qquad (1)$$

It is then customary to deduce from this a formula for the case of water flowing in a rectangular notch open above, as in fig. 2, by taking $h_1 = 0$, and so deriving, for the open notch, the formula

$$Q_{\textit{for notch}} = \tfrac{2}{3} c l\sqrt{2g}\;\, h_2^{\frac{3}{2}} \qquad (2)$$

These examples may suffice for indicating the nature of the method commonly advanced; and it may be understood that the same method with the necessary adaptations is usually given for finding the flow through circular orifices, triangular orifices, or orifices of any varied forms whatever.

Now this method is pervaded by false conceptions, and is thoroughly unscientific.

First. Throughout the horizontal extent of each infinitely narrow band of the area the motion of the water has not the same velocity, and has not the same direction at different parts, and the assumption of the velocity being the same throughout, together with the assumption tacitly implied of the direction of the motion being the same throughout, vitiates the reasoning very importantly. It is thus to be noticed at the outset that the division of the orifice into bands, infinitely narrow in height, but extending horizontally across the entire orifice, cannot lead to a satisfactory process of reasoning, and that the elements of the area to be separately considered ought to be infinitely small both in length and in breadth.

Secondly. For any element of the area of the orifice infinitely small in length and breadth *it is not the velocity of the water at it that ought to be* multiplied by the area of the element to find the volume flowing per unit of time across that element but it is only that velocity's component which is normal to the plane of the element that ought to be so multiplied.

Thirdly. Whether for any element of the area of the orifice, we wish to treat of the absolute velocity of the water there, or to treat of the component of that velocity normal to the plane of the orifice, it is a great mistake to suppose that the velocity at the element is that due by gravity to a fall from the still water surface level of the pent up statical water down to the element. The water throughout the area of any closed orifice in a plane surface, with the exception of that flowing in the elements situated immediately along the boundary of the orifice, has more than atmospheric pressure, and hence it can be proved * *that it must have less velocity than that due to the fall from the* still-water surface-level down to the element.

The foregoing may be illustrated by consideration of the very simple case of water flowing from a vessel through a rectangular orifice in a vertical plane face, two sides of the rectangle being level and the other two vertical, and end contractions being prevented by the insertion of two parallel guide walls or plane faces, one at each end of the orifice, and both extending some distance into the vessel perpendicularly to the plane of the orifice, so that the jet of issuing water may be regarded as if it were a portion of the flow through an orifice infinitely long in its horizontal dimensions.

Thus if the jet shown in section in fig. 3*a* be of the kind here referred to, while W L is the still water surface level, the so-called 'theoretical velocities' at the various depths in the orifice, which are dealt with as if they were in directions normal to the plane of the orifice, can be, and very commonly are, represented by the ordinates of a parabola as is shown in fig. 3*b*, where B D represents in magnitude and direction the "theoretical velocity" at the top of the orifice, C E the "theoretical velocity" at the bottom of the orifice, and F G that at the level of any point F in the orifice—these ordinates being each made $= \sqrt{2gh}$, where h is the depth from the still water surface down to the level of the point in the orifice to which the ordinate belongs. Then, under the same mode of thought, or same set of assumptions, the area of that parabola between the upper and lower ordinates (B D and C E) will represent what is commonly taken as the "*theoretical discharge*" per unit of time through a unit of horizontal length of the orifice. But this gives an excessively untrue representation of the actual conditions of the flow. Instead of the parabola, some other curve, very different, such as the inner curve sketched in the same diagram, fig. 3*b*, but whose exact form is unknown, would, by its ordinates, represent the velocity-components normal to the plane of the orifice for the various levels in the orifice, and its area would represent the real discharge in units of volume per unit of time through

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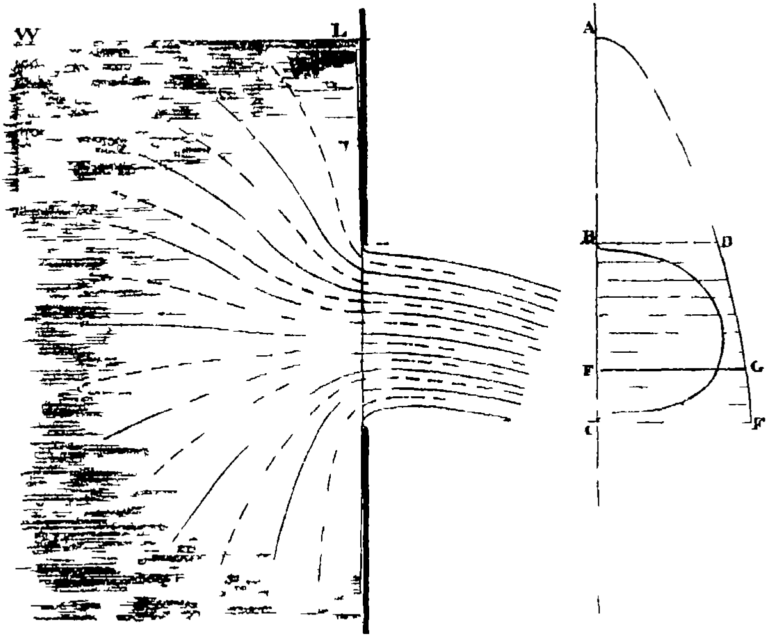
* Theorem I. further on will afford proof of this.

Fig. 3



3a 3b

a unit of horizontal length of the orifice. Although the exact form of this true curve is unknown, yet we may observe that it must have its ordinates each less than the ordinate for the same level in the parabola.

The truth of this may be perceived through considerations such as the following. First, it is to be noticed that for the very top and the very bottom of the orifice, instead of the ordinates B D and C E of the parabola, the ordinates of the true curve must be each zero, because, at each of these two places, the direction of the motion is necessarily tangential to the plane of the orifice*, and so the velocity component normal to the plane of the orifice must be zero, and that component, not the velocity itself, is what the ordinate of the true curve must represent On the hypothesis of perfect fluidity in the water (which throughout the present discussions and investigations, is assumed as being a close enough representation of the truth to form a basis for very good theoretical views) the velocities at top and bottom of the orifice will be those due by gravity to falls from the still water surface-level down to the top and bottom of the orifice respectively, because at these places the water issues really into contact with the atmosphere, and consequently attains atmospheric pressure At all intervening points in the plane of the orifice it may readily be seen, or may with great confidence be admitted that the pressure will be in excess of the atmospheric pressure because, neglecting for simplicity the slight and, for the present purpose, unimportant modification of the courses of the stream lines caused by the force of gravity acting directly on the particles composing the stream-lines, as compared with the courses which the stream lines would take if the action of gravity were removed and the water were pressed through the orifice merely by pressure applied as by a piston or otherwise, to the fluid in the vessel we may say, truly enough for the present purpose, that an excess of pressure at the convex side of any stream line is required in order that the water in the stream line can be made to take its curved path The mode of reasoning on this point suggested here may be obvious enough, although, for the sake of brevity, it is here not completely expressed It follows that at all these intervening points in the plane of the orifice the absolute velocity of the water will be less than that due to a fall from the still water surface down to the level of the point in the orifice, and besides, at all depths in the plane of the orifice except a single medial one, the direction of the flow will be oblique, not normal to the plane of the orifice Hence, further, through these two circumstances jointly or separately as the case may be, it follows obviously that the ordinates of the true curve will everywhere be less than those of the parabola

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* The assertion here made, to the effect that the directions of the stream-lines which form the external surface of the jet on its leaving the edge of the orifice must, at the edge, be tangential to the plane of the orifice when the orifice is in a plane face, or must in general be tangential to the marginal narrow band or terminal lip of the internal or water-confining face of the plate or nozzle in which the orifice is formed, can be clearly and easily proved, although, strangely, the fact has been and is still very commonly overlooked. Even MM. Poncelet and Lesbros, in their delineations of the forms of veins of water issuing from orifices in thin plates, after elaborate observations and measurements of those forms, represent the surface of the issuing fluid as making a sharp angle with the plane wetted face in leaving the edge ("Expériences Hydrauliques sur les Lois de l'Écoulement de l'Eau," a Memoir read at the Academy of Sciences in November 1829, and published in the Mémoires ... Sciences Mathématiques et Physiques, tome iii.). Other writers on Hydraulics put forward very commonly representations likewise erroneous. Weisbach, for instance, in his valuable works (Ingenieur und Maschinen Mechanik, vol. i. § 313, fig. 127, date 1846, and Lehrbuch der theoretischen Mechanik, 5th ed., date 1875, edited by Hermann, § 433, fig. 772) has assumed (not casually, but with deliberate care, and after experimental measurements made by himself) as the best representation which with available knowledge of the laws of contraction of jets of water can be given for the form of the

Fig 4 illustrates in like manner the false theoretical and the true actual conditions of the flow over a level upper edge of a vertical plane face, which may be exemplified by the case of a rectangular notch without end contractions, or of a portion of the flow not extending to either end in a very wide rectangular notch In this case it is to be observed that the ordinates at and near the top of the issuing water in the vertical plane of the orifice must be only slightly less than those of the parabola—because, at the very top or outside of the stream, atmospheric pressure is maintained throughout the length of any stream line, and so the velocity will be very exactly that due by gravity to the vertical depth of the flowing particle below the still-water surface level in the vessel and because, also, the direction of the

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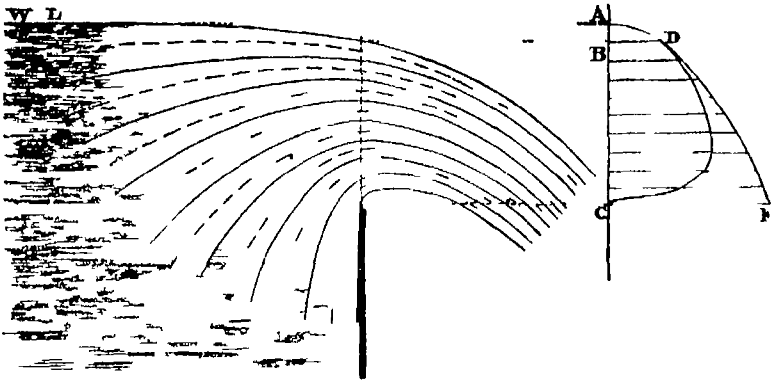
contracting vein of water issuing from a circular orifice in a thin plate a solid of revolution specified clearly in such a way that the water surface in leaving the plane of the plate makes an angle of about 67° with that plane and states to the effect that that water surface is just a continuation of the paths of the stream lines within the vessel which he represents at the margin of the orifice as crossing the plane of the orifice with converging paths making the angle already mentioned of about 67° with that plane They ought in reality to leave the lip tangentially to the plane and then to make a very rapid turn in a short space (or to have a very small radius of curvature) on just leaving the lip of the orifice The prevalence of erroneous representations and notions on this subject was adverted to and an amendment was adduced by myself in a *Report* to the British Association in 1861 on the Gauging of Water by V Notches (Brit Assoc Rep Manchester Meeting 1861 part 1 p 156)

4 *a* Fig 4 4 *b*



motion does not deviate much from perpendicularity to the plane of the orifice Lower down in the plane of the orifice the direction of the water's motion will approach still more nearly to being perpendicular to that plane but there the pressure will be considerably in excess of the atmospheric pressure and so the velocity will be considerably less than that due by gravity to a fall through the vertical distance from the still water surface-level down to the stream line in the plane of the orifice At places still further down in the orifice the flow comes to be obliquely upwards and this obliquity is so great as to render the normal component very much less than the actual velocity while the actual velocity itself is less than that due by gravity to the depth of the particle below the still-water surface level At this region of the flow then for both reasons, the ordinates of the true curve are less than those of the parabola Lastly, at the very bottom of the orifice, or immediately over the top of the crest of the notch the water issues into contact with the atmosphere, and so attains to atmospheric pressure, and must therefore have the velocity due by gravity to its depth below the still water surface-level Here, however, its direction of flow is necessarily tangential to the plane face of the vessel from which it is shooting away, and consequently is vertically upwards Hence the normal component of its motion is zero and so the ordinate of the true curve at that place is zero in length instead of the normal component being greater at the bottom of the orifice than at any higher level, and instead of that component being properly represented by the ordinate there of the parabola

Like explanations to those already given might be offered for other forms of orifices (for circular or triangular orifices or V notches, and for orifices in general which may be in vertical or horizontal or inclined plane faces, or in faces of other superficial forms than the plane), and it might be shown that in general the ordinary modes of treating the subject are very faulty

The examples already discussed may suffice to direct attention to the faulty character of the ordinarily advanced theories, and to give some suggestions of directions in which reforms are requisite

I will now proceed to offer some improved investigations which are applicable to many of the most ordinary and most useful cases in practical hydraulics, in reference to the flow of water through orifices in thin plates, or from the wetted internal surface of vessels terminating abruptly in orifices In devising and arranging these investigations I have aimed at putting them in such form as that they may be intelligible and completely demonstrative to students even in the early stages of their progress in dynamical studies

Definition —The *free level* for any particle of water in a mass of statical or of flowing water is the level of the atmospheric end of a column, or of any bar straight or curved, of particles of statical water, having one end situated at the level of the particle, and having at that end the same pressure as the particle has, and having the other end consisting of a level surface of water freely exposed to the atmosphere, or else having otherwise atmospheric pressure there, or briefly we may say that the *free level* for any particle of water is the level of the atmospheric end of its *pressure-column*, or of an equivalent ideal pressure-column

THEOREM I —*In the case of steady flow from approximate rest of water or any liquid considered as frictionless and incompressible, the velocity of any particle in the stream is equal to the velocity which a body would receive in falling freely from rest through a vertical space equal to the fall of free level which is incurred by the particle in the stream during its flow from rest to its existing position*

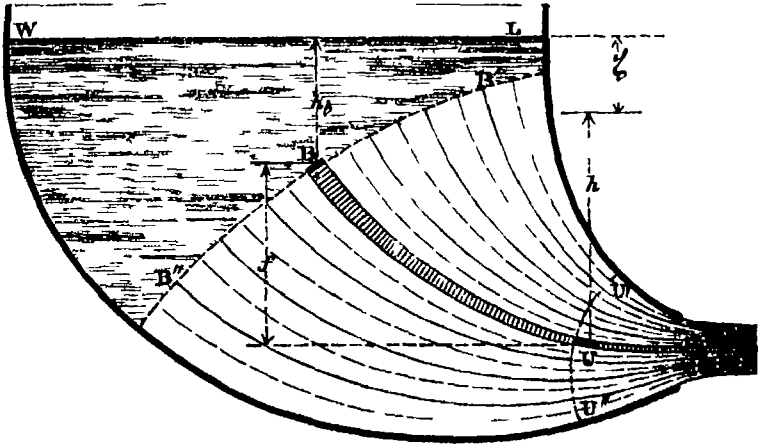
Or, in briefer words sufficiently suggestive, it may be said that, in respect to water or any liquid flowing so as to admit of its being regarded as truly enough frictionless and incompressible, *In steady flow, the velocity generated from rest is that due by gravity to the fall of free level*

Or if ζ be the fall of free-level sustained by any particle in passing from a statical region of the mass of water to a point in the region of flow, and if v be the velocity of the particle when at that point, then

$$v=\sqrt{2g\zeta}$$

In fig 5, let W L be the still-water surface level, and let B B B be a

Fig 5



bounding interface separating the region of flow with important energy of motion from the region which may be regarded as statical, or as devoid of important energy of motion Let U U U be another interface crossing the stream lines at any place in the region of flow

Now taking as the unit of volume the cube of the unit of length, taking as the unit of area the square of the unit of length taking the unit of density as unit of mass per unit of volume so that the density of a body will be the number of units of mass per unit of volume taking as the unit of force the force which acting on a unit of mass for a unit of time imparts to it a unit of velocity (that is to say, using the unit of force selected according to the system of Gauss, and which is often called the "absolute or the kinetic unit of force*), and taking water pressures as being reckoned from the atmospheric pressure as zero, let

ρ = density of the water

v = velocity at U

h_b = pressure height at B, or the height of a column of statical water which would produce the pressure at B

h = pressure-height at U

p_b = pressure in units of force per unit of area at B

p = pressure in units of force per unit of area at U

f = fall from B to U measured vertically,

ζ = fall of free level in the flow from the region of statical water to U,

then

$$p_b = g\rho h_b,$$

and

$$p = g\rho h$$

Let a small mass, m, of the water, whose volume (or content voluminally considered) is denoted by c, be introduced into the stream, its first place being at B just outside of the initial interface B B B, and let it flow forward in the stream till it reaches a second place at U where it is just past the interface U U U In the stream filament B U E the space between the two interfaces at B and U is traversed alike by both front and rear of the small mass m and therefore no excess of energy is given or taken by the mass in consequence of the pressure on its front and of that on its rear for the passage of its front from the interface at B to that at U, and of its rear over the same space

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* The units of force derivable by the method of Gauss from the various units of length mass and time in common use though spoken of under general designations such as *absolute units of force* or *kinetic units of force* have until lately been individually anonymous and this deficiency notwithstanding the important scientific and practical uses which these units were capable of serving has been a great hindrance and discouragement to their general employment in dynamical investigations and even to any satisfactory spread of knowledge of their meaning Three years ago the British Association Committee on Dynamical and Electrical Units (Brit Assoc Report 1873 part 1 p 222) taking the centimetre the gram and the second as units of length mass and time, named the force so derived the *Dyne* For the unit of force derived from the foot, the pound and the second the name *Poundal* has been introduced by myself and it seems likely to come into use At this Meeting of the British Association I have proposed the *Crinal* and the *Funal* as names for the two units of force derived respectively one from the decimetre the kilogram and the second, and the other from the metre the tonne and the second (see Proceedings of Section A in the present volume) The familiarization of these important units to the minds of students of dynamics will in a very important degree aid the acquisition of clear and true views in hydrokinetics as also in dynamics generally

But work given to it by pressure from behind, while it is passing the initial interface at B, is

$$=p_b \cdot c$$
$$=g\rho h_b \; c,$$

or that work is

$$=gmh_b,$$

since $\rho c=m$

Again, during the emergence of the mass past the interface at U, it gives away to the water in front of it a quantity of work which, in like manner, is

$$=p \cdot c$$
$$=g\rho h \; c$$
$$=gmh$$

Also during the passage of the particle from its first place at B to its place at U it descends a vertical space $=f$, hence during that passage it receives from gravity a quantity of work $=gmf$.

On the whole the mass receives an excess of work beyond what it gives, and that excess of work received is

$$=gmh_b+gmf-gmh$$
$$=gm(h_b+f-h)$$
$$=gm\zeta,$$

and as this is the work taken into store as kinetic energy, we have to put it $=\frac{mv^2}{2}$ That is,

$$gm\zeta=\frac{mv^2}{2},$$

or

$$v=\sqrt{2g\zeta},$$

which is the result that was to be proved in Theorem I.

THEOREM II.—ON THE FLOW OF WATER THROUGH ORIFICES SIMILAR IN FORM AND SIMILARLY SITUATED RELATIVELY TO THE STILL-WATER SURFACE-LEVEL.—*In the flowing of water, from the condition of approximate rest, through orifices similar in form and similarly situated relatively to the still-water surface-level**, *the stream-lines in the different flows are similar in form. also the velocity of the water at homologous places is proportional to the square root of any homologous linear dimension in the different flows · and also (pressures being reckoned from the atmospheric pressure as zero) the pressure of the water on homologous small interfaces in the different flows is proportional to the cube of any homologous linear dimension, or, in other words, the fluid pressure (super-atmospheric), per unit of area at homologous places, is proportional to any homologous linear dimension.*

Preparatively for the demonstration of this theorem, it is convenient to establish some dynamic principles, which, for present purposes, may be regarded as lemmas or preparatory propositions, and which will be grouped here together under the single heading of Proposition A.

PROPOSITION A.—*If there be two or more vessels containing water pent up in an approximately statical condition, and if they have similar orifices similarly situated relatively to the free level of the statical water—and if we imagine the*

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* Or *free level* of the still water

water to be guided in each case to and onward past the orifice by an infinite number of infinitely small frictionless guide-tubes arranged side by side, like the cells of a honeycomb, and having their walls or septums[*] *of no thickness—and if, in the different vessels, these guide-tubes be, one set to another, similar in form, though they may be of quite different forms from the forms which the stream-lines would themselves assume if the flows were unguided—and if, at the homologous terminations of the guide-tubes, fluid pressures be anyhow maintained proportional, per homologous areas, to the cube of any homologous linear dimension, or, what is the same, if pressures be maintained proportional, per unit of area, to the homologous linear dimension,—then the velocity of the water at homologous places will be proportional to the square root of the homologous linear dimension, and the pressure of the water at homologous places on homologous areas will be proportional to the cube of the homologous linear dimension, and the water will press, at homologous places, on homologous areas of the septums, with a force on one side in excess of that on the other, which will be proportional to the cube of the homologous linear dimension.*

NOTE.—For brevity in what follows, pressures at homologous places on homologous areas will be called *homologous pressures*, and pressures per unit of area will be called *unital pressures*, and any difference of the fluid pressures on the opposite sides of any small portion or element of a septum will be called a *differential pressure*

The demonstration of the proposition will be aided by first noticing the following relation in respect to two small solid masses in motion It two similar small solid bodies of masses m and m', having their homologous linear dimensions as 1 to n, are guided to move along similar curves, having likewise their homologous linear dimensions as 1 to n (fig 6), and if the velocities of the bodies at homologous points in their paths be as 1 to $\sqrt{n}$, then—

First Their gravities are as 1 to n^3, evidently

Second. Their "centrifugal forces"[†] applied by them in the plane of curvature and normally to the guide are also as 1 to n^3.

Let r and r' be put to denote the radii of curvature of the paths at homologous places Then centrifugal forces are as $\frac{mv^2}{r}$ $\frac{m'v'^2}{r'}$

But

$$m'=n^3m,$$
$$v'=\sqrt{n}\;v,$$
$$r'=nr$$

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[*] The English form for the plural of *septum*, when septum is used as an English word, is here purposely preferred to the Latin *septa*

[†] The name "*centrifugal force*" is here adopted in the sense in which it is commonly used I fully agree with the opinion now sometimes strongly urged to the effect that this name is not a very happily chosen one, for two reasons —first, because the name *centrifugal* would be better applied to a *motion* of flying from the centre, than to a *force* acting outwards along the radius, and secondly, because the body really receives no outward force, no force in the direction from the centre, but receives a centreward force which, being unbalanced, acts against the inertia of the body, and diverts the body from the straight line of its instantaneous motion The centreward force actually received by the body, and which is the force acting on it normal to its path, may be called the *deviative force* received by the body. This is equal and opposite to the outward force called "*centrifugal force*," which is not *received* by the body, but is exerted outwards by it against whatever is compelling it to deviate from the straight line of its instantaneous motion The name "centrifugal force," however, although objected to, is in too general use throughout the world to allow of its immediate abandonment.

Hence the centrifugal forces are

$$\text{as } \frac{mv^2}{r} : \frac{n^3m \, . \, nv^2}{nr},$$

$$\text{or as } 1 : n^3$$

This being understood, it readily becomes evident that if, instead of small solid masses sliding along guides, we have two small homologous masses of water m and m', fig. 7, flowing in similar slender guide-tubes, and if homologous pressures be applied to the two masses in front and behind, which are as 1 to n^3, and if at homologous situations in their two paths their velocities be as 1 to $\sqrt{n}$, then, in respect to all the forces received by the two masses from without, other than those applied by the guide-tubes, and also in respect to the forces required to be received for counteracting their centrifugal forces, we see that all these constitute force systems similar in arrangement and of amounts as 1 to n^3. It therefore follows that the forces which the masses must receive from their guide-tubes must be similarly arranged and of amounts, on homologous small areas, as 1 to n^3

Fig. 6

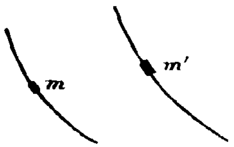
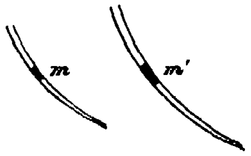


Fig. 7



This being settled, we may now pass to the demonstration of Proposition A, at present in question.

Suppose No. 1 and No. 2 in fig. 8 to represent two similar vessels with similarly guided flows, in all respects as described in the enunciation of this proposition. Let W L and W′ L′ be the still-water surface-levels, or the free levels of the still water in the two cases. Let B C D, B′ C′ D′ be two similar bounding interfaces, each separating the region of flow with important energy of motion from the region which may be regarded as statical, or as devoid of important energy of motion. Let B U E in No. 1 and B′ U′ E′ in No. 2 be two homologous guide-tubes, and let them for the present be understood as terminating at two homologous cross interfaces E and E′, which may conveniently be understood as being each situated at a moderate distance outside of the orifice—for instance, at some such place as that which is usually spoken of as being the "*vena contracta*," or where the water has attained a pressure not differing much from that of the atmosphere, or it may in some cases even be that the atmospheric pressure is there attained, but the exact places at which to suppose the homologous terminations E and E′ of the two guide-tubes as being taken are not at all essential to the demonstration.

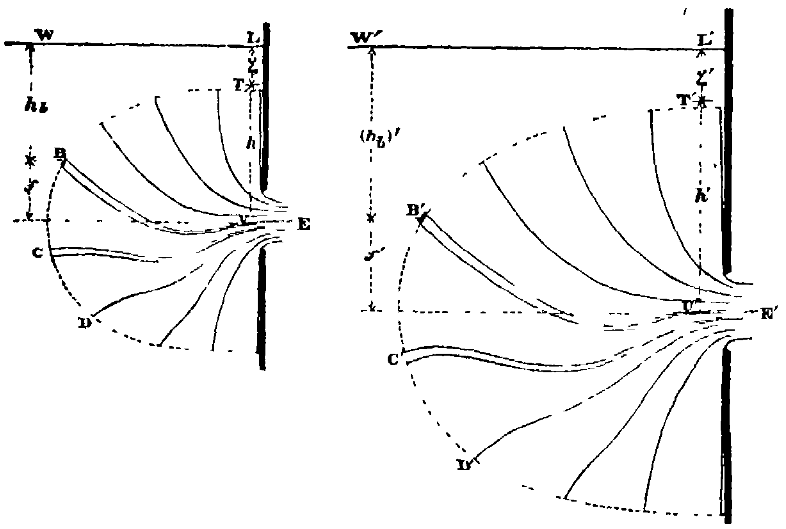
Let homologous linear dimensions in No. 1 and No. 2 be as 1 to n.

Let the velocity at any variable point U in the guide-tube B U E be denoted by v.

Let the pressure at U, expressed in units of pressure-height, be denoted by h; as shown by the vertical line U T in No. 1, where T is the top of the pressure-column for the point U.

Fig 8

No 1. No 2



Let the pressure at B, the beginning of the tube, on the initial interface, outside of which the water may be regarded as statical, or as having no important energy of motion, be denoted by h_b, or, what comes to the same thing, let the depth from the still-water surface-level down to the beginning of the tube at B be denoted by h_b, as is marked in the figure. It is thus to be noticed that the fall of free level incurred by a particle in flowing along the guide-tube from B to U is the vertical distance from the still-water surface-level, W L, down to T, the top of the pressure-column for the flowing water at U. This fall of free level may be denoted (in conformity with the notation in Theorem I.) by ζ.

Let the vertical descent from B to U be denoted by f; so that f is the fall of a particle in passing from B to U. In case of an ascent in any guide-tube, from its beginning to any point U in its course, we shall have the fall f negative.

Let the abatement of pressure-height from B to U be denoted by k, or let $h_b - h = k$. Thus in case of an increase of pressure-height in any guide-tube, from its beginning to any point U in its course, k will be negative.

For No. 2, let the same letters of reference to the diagram, and the same notation, be used as for No. 1, with the modification for No. 2 merely of the attachment of an accent to each letter.

Now as a part of the data on which the present investigation under Proposition A is founded, it is to be assumed that a unital pressure is somehow maintained at E', the end of the guide-tube in No. 2, n times that which is anyhow maintained at the corresponding point E in No. 1. Thus, if we denote these two pressures expressed as pressure-heights, at E and E' respectively, by h_e and $(h_e)'$, we have $(h_e)' = nh_e$, and hence the fall of free level from beginning to end in No. 2 is n times the fall of free level from beginning to end in No. 1.

Hence putting v_e and $(v_e)'$ to denote the velocities at E and E′ respectively, we have (by Theorem I., which proves that the velocities must be proportional to the square roots of the falls of free level)

$$v_e : (v_e)' :: \sqrt{1} : \sqrt{n},$$

or

$$(v_e)' = v_e\sqrt{n} \quad . \quad . \quad . \quad . \quad (1)$$

Again, from similarity of forms, we have in respect to areas of cross-sections of the two guide-tubes:—

$$\frac{\text{area at E}}{\text{area at U}} = \frac{\text{area at E}'}{\text{area at U}'};$$

or since reciprocals of equals are equal.—

$$\frac{\text{velocity at E}}{\text{velocity at U}} = \frac{\text{velocity at E}'}{\text{velocity at U}'},$$

or

$$\frac{v_e}{v} = \frac{(v_e)'}{v'},$$

or by (1)

$$\frac{v_e}{v} = \frac{v_e\sqrt{n}}{v'},$$

or

$$v' = v\sqrt{n}. \quad . \quad . \quad . \quad (2)$$

This applies to any or all homologous points in the two regions of flow

Now by referring to the figure or otherwise, it will readily be seen that ζ, or the fall of free level from B to U, is $= h_s + f - h$, while $k = h_s - h$; and that therefore $\zeta = f + k$. Hence, by Theorem I., we have

$$v = \sqrt{2g(f+k)}$$

In like manner in No. 2:—

$$v' = \sqrt{2g(f'+k')};$$

but by (2)

$$v' = \sqrt{n}\ v$$

Hence

$$\sqrt{2g(f'+k')} = \sqrt{n}\ .\ \sqrt{2g(f+k)},$$

or

$$f' + k' = nf + nk.$$

But by similarity of forms $f' = nf$.

Hence, subtracting equals from equals, we have

$$k' = nk; \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

but by similarity of forms $(h_s)' = nh_s$. . . . . (4)

Also, since the pressure at any point in a stream-line, or guide-tube, is its initial pressure minus the relief of pressure, we have

$$h_s - k = h \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and

$$(h_s)' - k' = h'. \quad . \quad . \quad . \quad . \quad . \quad (6)$$

From this last by (4) and (3) we get

$$nh_1 - nk = h \quad \text{or} \quad n(h_1 - k) = h$$

whence by (5)

$$h = nh \qquad (7)$$

From this if we put P and P to denote total pressures on homologous small areas at U and U it follows that

$$P = n^3 P \qquad (8)$$

This holds good for any homologous places in any homologous guide tubes, and so it holds for immediately adjacent places in any two contiguous guide tubes Hence, in respect to any small element of the septum between two adjacent guided stream filaments in Flow No 1 considered comparatively with a homologous element of a septum in Flow No 2, the homologous differential pressures in No 1 and No 2 will be as 1 to n^3

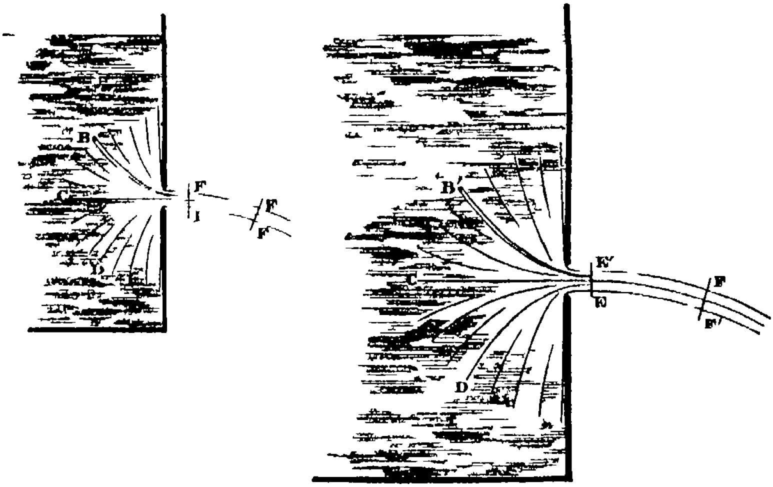
Thus the demonstration is now completed of all that is included in Proposition A and we are ready to go forward to the demonstration of Theorem II, for which Proposition A was meant to be preparative For this we have to observe that the conclusions arrived at in Proposition A hold good no matter what may be the forms of the guide tubes provided that they be similar in both flows and no matter what may be the distribution of pressures throughout a terminal interface crossing the assemblage of guide-tubes in No 1 provided that the homologous pressures throughout a homologous terminal interface in No 2 be anyhow maintained severally n^3 times those in No 1 Hence if in Flow No 1 the guide-tubes be formed so that the water shall flow along exactly the same paths as if it were left unguided, and were left free to shoot away past the interface at E, to a distance from the orifice great in proportion to the thickness of the issuing stream, without meeting any obstruction—and if the guide-tubes in No 2 be similar to them—and if in No 1 the system of pressures distributed throughout the terminal interface at E be made exactly the same as if the water were flowing freely for a great distance past that terminal interface—and if in No 2 the system of homologous distributed pressures throughout a homologous terminal interface at E be anyhow maintained severally n^3 times those in No 1,—it follows that the differential pressure on the two sides of any element of a septum in Flow No 1 will be zero, as the guide-tubes have there no duty to perform Then, on the homologous septum element in No 2, the differential pressure, being n^3 times that in No 1, will be zero also Hence in No 2 the guide-tubes have no duty to perform, and the water flows in them exactly as if it were left unguided, but had still throughout its terminal interface the stated system of distributed pressures somehow applied

Now, for completing the demonstration of Theorem II, nothing remains needed except to show that this stated system of distributed pressures requisite to be applied throughout the terminal interface at E will very exactly be applied on that interface backwards by the water in front of it, which constitutes, for the time being, the continuation of the stream past the interface

For proof of this, conceive any cross interface F F (fig 9) further forward in No 1 than E E is, and conceive a similarly situated cross interface F F in No 2 By exactly the same mode of reasoning as before (making use of the like supposed introduction and subsequent removal of guide-tubes), that reasoning being now applied to the two flows commencing at the initial interfaces B C D and B C D and continued to the terminal interfaces I F and I F, it results that if the jet in No 1 be allowed to flow freely to and far past the interface I I the jet in No 2 terminating at F F can be left to flow unguided with stream lines similar to those in No 1, and with the same relations of pressures and velocities at its various places to the pressures and velocities in No 1 as have been already proved for the flow terminating at I L provided that homologous pressures n^2 times those at I I be likewise maintained at I F Thus then we see that if adjusted or requisite pressure systems such as have been already fully explained be maintained at I F and F I the two streams one extending backward from F F to I I and the other from F F to I I will transfer backward just such pressures to successive places in retrograde order in their courses as that they will of themselves apply at the interfaces F F and F F exactly the already specified requisite pressure systems Thus we can depart

Fig 9

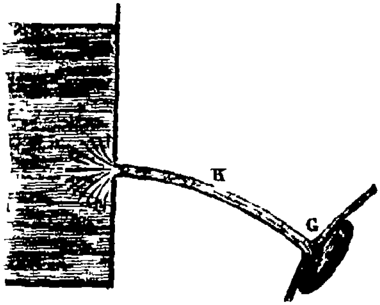
No 1 No 2



as far as we please from the orifices forward along the two streams to the places where, for purposes of reasoning, certain definite pressures are to be supposed to be applied in two homologous cross interfaces Now it may be taken as evident that, by going far enough away from the orifice to the terminal cross interface, we can make, for any disturbances or departures from the specified pressure relations, the effects propagated backwards to the water in and near the orifices as small as we please or that, even if we were to apply not exactly the strictly requisite pressure systems at those terminal places, still the effects of this departure from perfect exactitude would fade away rapidly in either stream as we transfer the place under consideration backwards against the current towards the orifice In corroboration of this, observation on the flow of water spouting from an orifice may be appealed to as setting this matter beyond doubt, through its showing that any changes of pressure introduced in a jet of water at any place far away from the orifice (as, for instance, by the insertion of a rigid obstruction) will transmit scarcely the slightest effect back to the region of the orifice; or, in other words, that in a free-flowing jet spouting through the air, the effects of obstructions fade away rapidly in the direction contrary to the current, so as to become imperceptible at a very moderate distance taken back from the obstacle in the direction against the flow—very moderate relatively to the thickness of the jet.

Even without this appeal to experimental observation, we might almost intuitively perceive, or might readily admit, that the introduction of more or less pressure than any stated amount in the stream, at a place where it has got well clear of the orifice, would be only very slightly influential on the flow as to pressures and as to velocities and directions of motion within the vessel and near the orifice and contracting vein. A reason for this is, that while an obstruction in a free jet will require a great change in mode of flow of the jet close in front of it, yet the jet approaching to that region need have its outer filaments turned aside only very slightly indeed to allow of all parts moving forward without any of their stream-lines, whether medial or at or near the surface, being subjected to almost any increase of pressure, and consequently without the velocities of any of them being almost at all retarded. This will readily be clearly understood by reference to fig. 10, where the water is shown as spouting against a stone without being made to thicken its stream sensibly in consequence of the obstruction, except for a very short distance at G in front of the stone—that is to say, in the back-stream direction from the stone. If we were to suppose that the stone would have a tendency to produce, at such a place as K, any considerable increase of pressure in the internal or central stream-filaments of the jet, we would have to notice that the external stream-filaments next the atmosphere would fail to resist this augmented pressure; and, instead, they would, with only a very slight change in their own velocities or pressures, yield a little outwards, and so would not exert on the internal filaments the confining action that would be requisite for the maintaining of more than an extremely slight augmentation of pressure in those internal filaments. Then it is obvious that if the pressure is very little augmented, the velocity must be very little abated; and so, for this reason, the stream will not tend to thicken itself except very slightly, because any considerable increase of cross-sectional area of the stream would require an important abatement of velocity, which, as said before, would require a great increase of pressure in the internal

Fig. 10.



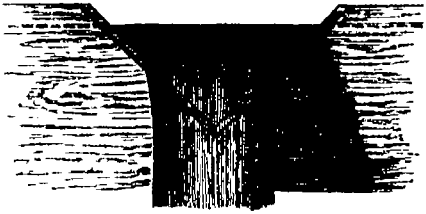
filaments, while the external filaments would fail to exert that necessary confining pressure. These external filaments could, with very little change in their own velocities, allow even of a great augmentation of the cross-sectional area of the jet if the internal filaments, by abated velocity, were requiring to become considerably thicker than before, in virtue of the introduction of the obstruction It is only the rapid change of direction of motion of the particles of water in the outer filaments in the neighbourhood of G, close to the obstruction, that enables them, by what may be called their centrifugal force, to maintain a greatly increased internal pressure very close to the obstruction, and so to allow of the water in the internal stream-filaments abating its velocity, and of those filaments themselves swelling in their transverse dimensions

These considerations complete all that is necessary for the demonstration of Theorem II., and it may now be regarded as proved

FORMULA FOR THE FLOW OF WATER IN THE V-NOTCH

From the foregoing principle we can find intuitively the formula for the quantity of water which will flow through a V-notch in a vertical plane surface, as in fig 11 We can see it at once by considering any stream-filament in the flow in one notch, and the homologous stream-filament in the simila flow in another notch similarly formed, but having its vertex at a different depth below the still-water surface-level. Let the ratio of the depth of the vertex of the one notch below the still-water surface-level to the depth of the vertex of the other be as 1 to n, so that all homologous linear dimensions in the two flows will be likewise as 1 to n Then, in passing from any cross section of one of the two homologous filaments to the homologous cross section of the other, we have the cross-sectional area $\propto n^2$, and the velocity of flow $\propto \sqrt{n}$; and the volume of water flowing per unit of time, being as the cross-sectional area and the velocity conjointly, will vary as we pass from the one to the other of the pair of homologous filaments, so as to be $\propto n^2\sqrt{n}$. Then, as this holds for every pair of homologous stream-filaments throughout the two flows, if we put Q to denote the quantity, reckoned voluminally, flowing per unit of time in each of the two entire flows, we have

Fig 11.



$$Q \propto n^{\frac{5}{2}}.$$

Now, as well as considering two separate notches with different streams flowing in them at the same time, we may, when it suits our purpose, consider one single notch with streams of different depths flowing at different times, and if in various cases, either of the same V-notch or of different but similar **V**-notches, we denote the height of the still-water surface-level above the level of the vertex of the notch by h, we have

$$Q=ch^{\frac{5}{2}}, \tag{9}$$

where c is a constant coefficient, which cannot be determined by theory, but can be very satisfactorily determined by experiment for any desired ratio of horizontal width to vertical depth to be adopted for the form of the notch. Experiments determining the values of c for certain forms and arrangements of **V**-notches, suited for practical convenience and utility, have already been made by myself, and have been reported on to the British Association, and the Reports on them are printed in the British Association volume for Leeds Meeting, 1858, and in that for Manchester Meeting, 1861.

INVESTIGATION OF A FORMULA FOR THE FLOW OF WATER IN A RECTANGULAR NOTCH WITH LEVEL CREST IN A VERTICAL PLANE FACE.

It is to be premised that the long-known and generally used formulas for the flow of water in rectangular notches, brought out by the so-called "theories" which I have dissented from in the earlier part of the present paper, have been mainly of the form

$$Q=cg^{\frac{1}{2}}Lh^{\frac{3}{2}},$$

where Q denotes the volume per unit of time,
L denotes the horizontal length of the notch,
h the vertical height from the crest of the notch to the still-water surface-level, and
g the coefficient for gravity,
and where c has either been taken as a constant numerical coefficient for want of accurate experiments to determine its values for different values of L and h, or has been treated as a variable. Poncelet and Lesbros have taken this latter course, and have deduced by experiments extensive tables of its values for different depths of water in notches of the width on which they experimented—a width, namely, of 20 centimetres*. As, however, the coefficient for terrestrial gravity varies but little for different parts of the world, it has most frequently been left out of account, a single coefficient c' being used instead of cg; so that if, for instance, when the foot and second are used as units of length and time, we take 32·2 as a correct enough statement of the value of g for any part of the world, we have $c'=32{\cdot}2c$.

A new formula, involving an important improvement in its form and adjusted so as to be in due accordance with numerous elaborate experiments, was developed within or about the time from 1846 to 1855, in America, by Mr. Boyden and Mr. Francis, both of Massachussetts. It is

$$Q=3{\cdot}33\left(L-\tfrac{1}{10}nh\right)h^{\frac{3}{2}},$$

where Q is the quantity of water in cubic feet per second,
L is the length of the notch in feet,
h is the height from the level of the crest to the still-water surface-level in feet, and
n is the number of end contractions, and must be either 0, 1, or 2.

---

* Mémoires de l'Académie des Sciences. Sciences Mathématiques et Physiques, tome iii. 1829.

This formula was offered by Mr. James B. Francis, in his work entitled "Lowell Hydraulic Experiments," and published at Boston in 1855, not as one founded on any complete theoretical views, but as one depending on several assumptions probably not perfectly correct, and yet as one which, through numerous trials and by adjustments introduced tentatively in fitting it to experimental results, had been brought out so as to agree very closely with experiments.

In § 120, at page 72 of his work, Mr. Francis says:—"No correct formula "for the discharge of water over weirs, founded upon natural laws, and including the secondary effects of these laws, being known, we must rely "entirely upon experiments, taking due care in the application of any formula "deduced from thence not to depart too far from the limits of the experiments "on which it is founded." And in §§ 123, 124, at page 74, in respect to the conception of the formula, he further gives the following very clear explanations:—"The contraction which takes place at the ends of a weir diminishes the discharge. When the weir is of considerable length in proportion "to the depth of the water flowing over, this diminution is evidently a constant quantity, whatever may be the length, provided the depth is the same; "we may, therefore, assume that the end contraction effectively diminishes the "*length of such weirs, by a quantity depending only upon the depth upon* "the weir. It is evident that the amount of this diminution must increase "with the depth; we are unable, however, in the present state of science, to "discover the law of its variation; but experiment has proved that it is very "nearly in direct proportion to the depth. As it is of great importance, in "practical applications, to have the formula as simple as possible, it is assumed "in this work [Mr. Francis's book] that the quantity to be subtracted from "the absolute length of a weir having complete contraction, to give its effective "length, is directly proportional to the depth. It is also assumed that the "quantity discharged by weirs of equal effective lengths varies according to a "constant power of the depth. There is no reason to think that either of "these assumptions is perfectly correct; it will be seen, however, that they "lead to results agreeing very closely with experiment.

"The formula proposed for weirs of considerable length in proportion to "the depth upon them, and having complete contraction, is

$$"\ Q=C(L-bnh)h^{a},$$

"in which Q = the quantity discharged in cubic feet per second;
"C = a constant coefficient;
"L = the total length of the weir in feet;
"*b* = a constant coefficient;
"*n* = the number of end contractions. In a single weir having complete contraction, *n* always equals 2, and when the length of the weir is equal to the width of the canal leading to it, *n* = 0;
"*h* = the depth of water flowing over the weir taken far enough upstream from the weir to be unaffected by the curvature in the surface caused by the discharge;
"*a* = a constant power."

This formula, Mr. Francis states, was first suggested to him by Mr. Boyden in 1846.

The important novel feature in this formula consists in the subtraction which it makes, from the length L of the notch, of a length for each end contraction directly proportional to the height of the still-water surface-level above the crest in order to find what may be treated in the formula as the *effective length*

The formula in its general form here last noted expressed only in symbols, as also in its subsequently developed form here previously stated with numerical coefficients arrived at by tentative application of numerous experiments, is thus to be regarded as an ingeniously arranged and valuable empirical formula, but not as one founded on any trustworthy hydrokinetic theory. It is founded partly on the old ordinary false "theoretical" views, and partly on good conjectural assumptions, and is adjusted and approximately verified by elaborate experiments conducted on a scale unusually large, and with unusually good means for attainment of exact results. Mr. Francis, it is to be noticed, explains that, in the formula as finally brought out, the index for the power of the height of the water is taken as an exact fraction, $\frac{3}{2}$, in preference to some unascertained fractional expression, different in no great degree from $\frac{3}{2}$, merely for the attainment of facility in calculations in the practical applications of the formula, and not for any theoretic reason. Also it is to be noticed, in respect to the value $\frac{1}{10}$ which he assigned for the symbol b, that the symbol itself was first assumed as a *constant* rather than some unknown *variable* dependent on h, and was afterwards fixed at the particular value $\frac{1}{10}$ for the sake, in both cases, of attaining a convenient degree of simplicity which by trials was found to be attainable, consistently with good accordance between the representations afforded by the formula and the results shown by experiments He supposed, however, that "many other values of a and b (probably an unlimited number) might "be found that would accord somewhat nearer with the experiments"*.

Many years ago, after my having become acquainted with the empirical formula thus made out by Mr Boyden and Mr Francis, it occurred to me as desirable to attempt to investigate by hydrokinetic principles, without special experiments, a true formula for the flow of water in rectangular notches in vertical thin plates, or vertical plane faces, on the hypothesis of the water being a perfect or frictionless fluid, and by using in the formula symbols for constant coefficients, which, after the finding of the formula, might be determined by a small number of accurate experiments, and might further be tested as to their trustworthiness, or might be amended so as to become more exact, by a large number of varied experiments. It will be interesting to notice that the formula which had previously been arrived at in America by Mr Boydon and Mr Francis in the way already described is in perfect agreement with the formula which, by my own investigation, is brought out by strict scientific principles as a highly exact formula for water considered as a perfect fluid, and as being a very satisfactory representation of the truth for real water.

It is to be noticed at the outset that obviously a notch may be made so long relatively to the depth of its crest from the still-water surface-level, that, for any additional length, the increase of the flow will be proportional to the additional length. Let mh, in which m is a constant multiplier, be such a length as that, for additional length, the additional flow will be proportional to the addition made to the length In fig. 12 let A B be the crest of the notch, and let C D be the level of the still-water surface of the pent-up water Let A E and B F be each equal to $\frac{1}{2}mh$, so that, over the part E F of the crest there will flow a quantity of water exactly proportional to the length of F F if the width of the notch be varied while the depth h of the water remains unchanged Let the length F I be denoted by l then

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* Lowell Hydraulic Experiments, § 156, p 118, § 153, p 116, and the passage quoted above from § 123, p. 74

$$l = L - mh$$

Now out of the entire flow conceive the middle portion which flows over F F and may be regarded as bounded laterally by two vertical planes perpendicular to the plane of the orifice one passing through F R and the other through F S to be taken away and suppose the two remaining parts which flow over A F and F I with the necessary lateral parts of the notch plate to be brought together as shown in fig 13 so as to form one notch having

Fig 12

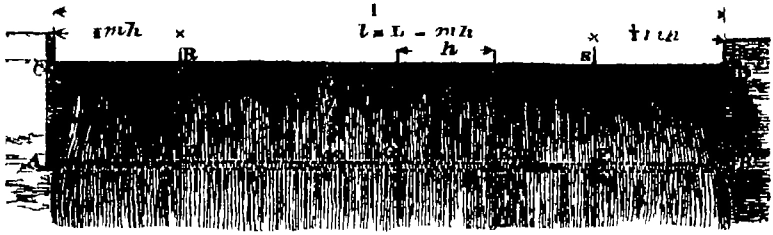
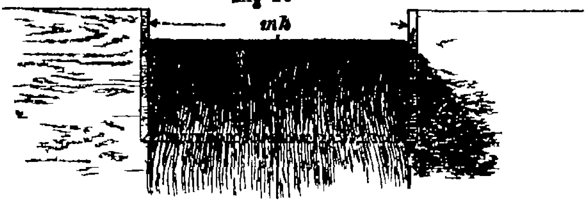


Fig 13



mh for its width and h for the height from crest to still water level and in which, therefore, the width of the notch shall bear a constant ratio to the height of the water when the height varies, the width being always m times the height

Then by exactly the same mode of procedure as that already used for finding a formula to show how the quantity of water flowing in a V notch varies with the depth of the vertex or with any other linear dimension of the flowing stream, we can readily see that if we put Q to denote the volume of water flowing per unit of time in the case represented in fig 13 we shall have

$$Q = ah^2\sqrt{h} \tag{10}$$

where a is a constant coefficient

Next to find an expression for the quantity (voluminally reckoned) flowing over the middle part F I of the crest we may consider first, of that middle part a portion G K taken always of a length bearing a constant ratio to h, and for simplicity we may take it of length equal to h* Now in this stream, since the width has in general a constant ratio to the depth, or, in the case more particularly considered, since the width is equal to the depth, the quantity flowing per unit of time will, as in the preceding case, be proportional to the $\frac{5}{2}$ power of the depth, or we have

---

* Or to meet the case in which there might not be between E and F a length so great as h we might as well consider in another notch having great width and having a height of flow equal to h a portion of the flow not near either lateral extremity of the notch and occupying a length of the crest equal to h

$$\text{Flow over GK} = \beta h^2\sqrt{h}, \text{ where } \beta \text{ is constant}$$

Hence if q_1 be the flow, in units of volume per unit of time, over a unit of length in E F, we have

$$q_1 = \beta h\sqrt{h}$$

By multiplying this by l we get the quantity flowing over the entire middle part E F per unit of time, and so, denoting that quantity by Q″, we have

$$\left.\begin{aligned} Q'' &= \beta lh\sqrt{h}, \\ \text{or} \quad Q'' &= \beta(L - mh)h\sqrt{h} \end{aligned}\right\} \quad . \quad (11)$$

Adding the expressions for Q′ and Q″ together, we get for the total flow in the whole notch, which we may denote by Q,

$$Q = \beta(L - mh)h\sqrt{h} + \alpha h^2\sqrt{h}.$$

$$\text{or} \qquad Q = \beta Lh\sqrt{h} - (\beta m - \alpha)h\sqrt{h},$$

$$\text{or} \qquad Q = \beta\left(L - \frac{\beta m - \alpha}{\beta}h\right)h^{\frac{3}{2}}$$

But $\frac{\beta m - \alpha}{\beta}$ is a constant, and let it be denoted by $2b$, and instead of the constant β we may, in order now to use English letters, put a Then

$$Q = a(L - 2bh)h^{\frac{3}{2}}, \quad . \quad . \quad . \quad (12)$$

which is the desired formula for the flow of water in a rectangular notch with two end contractions

This formula admits of easy modification to give a formula suitable for a notch with only one end contraction*, thus —

Let the width of the notch with only one end contraction be denoted by L (as in fig. 14) Then conceive a notch twice as wide with two end contractions as shown in fig. 15 The flow in this double space will, by the formula last obtained (12), be seen to be $= a(2L - 2bh)h^{\frac{3}{2}}$, and so if we put now Q to denote the flow in the notch under consideration (shown in fig 14), which will be half the flow in fig 15, we have for the notch with only one end contraction

$$Q = a(L - bh)h^{\frac{3}{2}} \quad . \quad . \quad (13)$$

---

* It is to be understood that contraction may be prevented at either end of a notch by there being a vertical plane side face for the channel of approach to the notch, that side face being perpendicular to the plane of the notch, and extending up-stream from the notch so as to reach beyond the region of incipient rapid flow to the notch, and extending for little way down-stream past the notch, so as to afford the necessary guidance to the issuing stream-filaments In like manner, by two parallel vertical side walls or side faces to the channel, when the crest of the notch extends quite across from the one wall-face to the other, contraction may be prevented at both ends

Fig 14

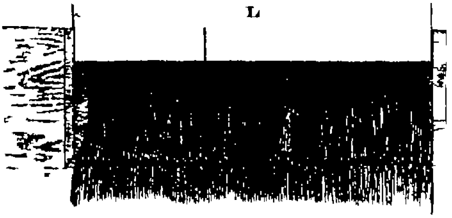
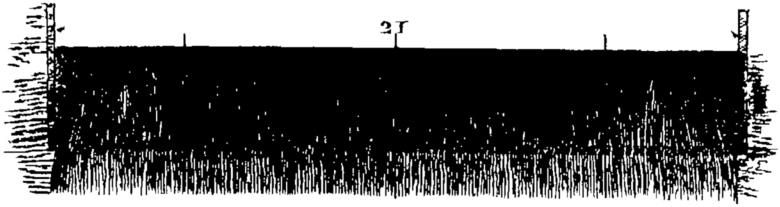


Fig 15



Also from (11) by changing as done before the letter β into the English letter a we see that for a notch with no end contraction (contractions being prevented at both ends by vertical guiding side faces perpendicular to the plane of the notch) we would have

$$Q=aLh^{\frac{3}{2}} \qquad (14)$$

Now the three formulas (12) (13) and (14) may be combined so as to be expressed together, thus —

$$Q=a(L-nbh)h^{\frac{3}{2}} \qquad (15)$$

where n is the number of end contractions and must be either 2, 1, or 0

To determine the constants a and b all that would be necessary would be to have two very accurate experiments on the flow of water in one notch at different depths or in two notches of the same kind with the ratio of the width to the depth not the same in both Then putting into the formula the measured values of L h and Q for the one experiment, and then again those for the other, we would have two equations with two unknown symbols, and so we could find the numerical values of those symbols It would, of course be desirable for experimental verification of the theory on which the formula is founded as also for mutual verification or testing of the experimental results themselves, to have numerous experiments on the flow for various depths in various notches of different widths, so as to find whether the formula would fit satisfactorily to them all, or to all of them that, after comparison, would be found trustworthy provided that the width of the notch be not too small in proportion to the depth of the flow, or that in all cases the width be sufficient to allow of there being at least some small part in the middle where the rate of flow per unit of time would be proportional to the length of the part of the crest to which that flow would belong

Mr Francis's experiments and his reductions of the results carried out in his own way give the formula complete, with its numerical coefficients, as follows*:—

$$Q=3.33(L-n\tfrac{1}{10}h)h^{\frac{3}{2}},$$

where Q = the discharge in cubic feet per second,
L = the length of the notch in feet,
n = the number of end contractions,
h = the height from the crest to the still-water surface-level in feet

Mr. Francis also states that this formula is not applicable to cases in which the height h from the crest to the still-water surface-level exceeds one third of the length, nor to very small depths In the experiments from which it was determined the depths varied from 7 inches to 19 inches, and he remarks that there seems no reason why it should not be applied with safety to any depths between 6 inches and 24 inches.

Report of the Anthropometric Committee, consisting of Dr. BEDDOE, Lord ABERDARE, Dr FARR, Mr FRANCIS GALTON, Sir HENRY RAWLINSON, Colonel LANE FOX, Sir RAWSON RAWSON, Mr. JAMES HEYWOOD, Dr. MOUAT, Professor ROLLESTON, Mr. HALLETT, Mr FELLOWS, *and* Professor LEONE LEVI

The Anthropometric Committee have been engaged during the past year in preparatory work They have secured the cooperation of gentlemen holding positions under Government as inspectors of the army, of the navy, of factories, and of pauper schools. They have prepared schedules and instructions, and have had them printed. and they have purchased a small outfit of instruments to send to places where measurements are to be made in large numbers.

Under these circumstances they are unable to make a report of anthropometric results, neither have they been called upon to expend more than a small portion of the grant of £100 that was made to them in 1875, the larger part of which will be required to pay for the reduction of observations. Consequently they ask that the Anthropometric Committee may be reappointed, with modifications, and that the grant may be carried forward to the year 1876.

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* Lowell Hyd Exp § 164, page 133

On Cyclone and Rainfall Periodicities in connexion with the Sun-spot Periodicity. By CHARLES MELDRUM.

[*Printed in extenso* by the authority of the Council.]

IN continuation of the paper on this subject published in the Report for 1874 (pp. 218–240), I beg to submit the following brief discussion of the cyclones of the Indian Ocean, between the equator and 34° S., in the years 1868–75, and of the rainfall in different places from 1854 to 1872.

Cyclones.

The number of cyclones in each year, the positions of their centres at noon on each day, their extent, duration, &c. have been approximately determined in the way already described, and the results are given in Table I.

From that and the similar Table given in 1874 we obtain the following general results for the twenty years 1856–75:—

Years	Number of cyclones	Total distance traversed	Sum of radii	Sum of areas	Duration in days	Sum of total areas.	Relative areas	Wolf's relative sun-spot numbers
		miles	miles	sq. miles		sq. miles		
1856	6	850	815	356,468·5	20	1,221,931·0	1·00	4·2
1857	5	1850	740	354,820·0	19	1,270,130·0	1·04	21·6
1858	12	3880	1656	775,215·8	39	2,890,781·7	2·37	50·9
1859	14	5040	2026	1,107,440·4	48	4,809,189·9	3·94	96·4
1860	13	8054	3131	2,620,929·9	61	13,616,789·7	11·14	98·6
1861	12	8730	2861	2,349,552·1	72	14,937,690·7	12·23	77·4
1862	14	6140	2968	2,406,879·1	57	11,370,279·7	9·53	59·4
1863	9	6320	2137	1,590,155·7	59	7,550,447·3	6·18	44·4
1864	7	4920	1341	876,628·5	36	4,893,009·5	4·00	46·9
1865	8	3970	1426	904,150·4	28	3,396,409·1	2·78	30·5
1866	8	3130	960	509,961·2	44	2,762,221·2	2·26	16·3
1867	6	2280	881	415,196·9	27	1,914,820·5	1·57	7·3
1868	9	4168	1229	589,725·5	34	2,612,102·3	2·14	37·3
1869	10	4390	1600	834,409·0	36	3,019,078·0	2·47	73·9
1870	16	4610	1832	739,734·1	62	3,830,051·8	3·13	139·1
1871	13	4710	1885	908,943·5	46	3,828,695·5	3·13	111·2
1872	12	7620	1830	954,732·2	48	5,036,927·6	4·12	101·7
1873.	11	5195	1510	714,871·2	46	3,781,622·7	3·09	
1874.	12	4685	1510	676,386·6	46	3,447,906·6	2·82	
1875	8	1770	940	396,469·8	30	1,700,861·8	1·39	

It will be seen that, on the whole, the number of cyclones increased from 1857 to 1862, decreased from 1862 to 1867, then increased to 1870, and again decreased to 1875.

The distances traversed had nearly a similar progression, increasing from 1856 to 1861, decreasing from 1861 to 1867, then increasing to 1872, and again decreasing to 1875.

The areas have been determined by finding as nearly as possible the radii of the spaces (considered more or less circular) over which the wind blew with the force of a 'strong gale.' They therefore are not the entire areas. But, apart from this, owing to incomplete information, the radii are not known for each day, and hence the areas are only rough approximations. There is no doubt, however, that they increased from 1856 or 1857 to 1860, decreased from 1860 to 1867, increased from 1867 to 1872, and then decreased to 1875.

On the whole there was a similar progression in the duration of the cyclones, the smallest number of days being in 1856, 1857, 1867, and 1875, and the greatest in 1861 and 1870.

The total areas, *i.e.* the products of the mean area of each cyclone by the number of days it lasted, increased from 1856 to 1861, decreased from 1861 to 1867, increased from 1867 to 1872, and then decreased to 1875.

It is to be remarked, however, that the total areas for the years 1860-62 were much greater than those for the years 1870-72. This may be owing partly to the radii for the latter years having been underestimated. On the other hand, the number of cyclone-days in the years 1870-72 was somewhat greater than in the years 1859-61.

Rainfall.

A sufficient number of rainfall returns for the years 1873-75 have not yet been obtained; but the annual mean rainfalls at seventy-seven stations from 1854 to 1863, and at seventy-two stations from 1864 to 1872, are given in Table II., in which all the rainfall observations at my disposal have been used, except a few Prussian and Mauritius ones, which would not have affected the general results.

The Table shows that, with hardly an exception, the sun-spots and rainfall were both above or both below their respective averages in the same years.

By taking the longer period 1843-72, and expressing the amounts of rainfall and sun-spots in percentages, we get the following results:—

Years	Difference from mean of sun-spot numbers	Difference from mean of rainfall	Years	Difference from mean of sun-spot numbers	Difference from mean of rainfall
1843	−0·83	·015	1858	+0·06	−·010
1844	−0·75	·008	1859	+1·01	+·022
1845	0·28	·032	1860	+1·06	+·112
1846	0·09	−·005	1861	+0·62	+·082
1847	+0·54	+·018	1862	+0·24	+·0[illegible]
1848	+0·95	+·045	1863	0·07	−·005
1849	+0·86	+·010	1864	−0·25	−·017
1850	+0·25	+·012	1865	−0·51	−·006
1851	+0·20	+·002	1866	−0·74	−·032
1852	+0·02	−·002	1867	−0·88	−·002
1853	−0·27	−·037	1868	−0·41	+·012
1854	−0·60	−·055	1869	+0·18	+·010
1855	−0·86	−·060	1870	+1·22	+·002
1856	−0·91	−·007	1871	+0·77	+·037
1857	−0·55	·075	1872	+0·62	+·100

From 1843 to 1856 there were eighty four stations from 1856 to 1867 seventy-seven stations, and from 1867 to 1872 seventy two stations in various parts of the globe, and in making the comparisons the same stations have been used

Comparing with the sun spots the depths of water given by Herr Gustav Wex* for one or more of the rivers Elbe Rhine Danube Oder and Vistula we obtain for the six sun spot periods from 1800 to 1867 the following Table in which the numbers in the first column represent the years viz No 1 the years 1800 1812 1824 1833 1844 and 1856 and so on ΔD the variations of the water depths, and Δr the variations of the sun spots —

Mean period	ΔD	Δr
	ft in.	
1	−0 04	27 8
2	0 23	17 0
	0 35	+ 3 8
4	0 03	+27 0
5	+0 45	+44 2
6	+0 67	+30 8
7	+0 40	+15 5
8	0 12	+ 28
9	−0 2	− 8 4
10	−0 9	−20 2
11	−0 33	−26 6
12	−0 14	−23 8

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* Ueber die Wasserabnahme in den Quellen Flussen und Stromen. Wien 18

TABLE I —Showing the duration extent &c of Cyclones experienced in the Indian Ocean from 1867 to 1875

Date		Number of Cyclone	Distance traversed	Mean Radius	Area πr^2	Duration	Total Cyclon Area $D\pi r$	Remarks
1867			miles	miles	square miles	day	square miles	
January	15 to 19	I	660	181	10 9 1 9	5	4600 5	In this year no severe cyclone took place
February	1 2	II	240	150	70686 0	2	1413 2 0	
	14 20	III	600	150	70686 0	7	49480 0	
April	11 14	IV	Stationary [9]	120	45239 0	4	18096 0	
May	24 28	V	540	160	80425 0	5	40212 0	
December	15 18	VI	240	120	45239 0	4	180956 0	
Total		6	2280	881	415196 9	27	1914820 5	

TABLE I (*continued*)

Date.	Number of Cyclone.	Distance traversed	Mean Radius	Area, πr^2	Duration	Total Cyclone Area, $D\pi r^2$	Remarks.
1868.		miles.	miles	square miles	days	square miles	
January 2 to 5	I	780	158	78426·9	4	313707·6	The severest cyclone in this year was No V., its centre passed near Mauritius, and it did great damage there Nos III., VIII., and IX were only heavy gales
16 „ 18 ...	II	380	188	111036·7	3	333110·1	
24	III.	Stationary ?	120	45239·0	1	45239·0	
February 2 „ 8	IV	1436	124	48305·2	7	338136·4	
March 9 „ 14 .	V.	940	235	173494·9	6	1040969·4	
April 20	VI	Stationary	85	22698·1	1	22698·1	
23	VII	„	85	22698·1	1	22698·1	
May 3 „ 8	VIII.	„	134	56410·6	6	338463·6	
November 9 „ 13	IX.	630	100	31416·0	5	157080·0	
Total	9	4166	1229	589725·5	34	2612102·3	
1869							
January 20 to 24	I	300	150	70686·0	5	353430·0	Nos I IV V VII and IX only attained the force of 9 and 10 of Beaufort's scale The severest were Nos. III., VI., and X.
February 8 „ 12	II	580	160	80425·0	5	402125·0	
17 „ 19 .	III	820	160	80425·0	3	241275·0	
24 „ 26	IV	420	180	101787·8	3	305363·4	
March 24 „ 25	V	Stationary ?	120	45239·0	2	90478·0	
April 8 „ 10	VI	880	240	180956·2	3	542868·6	
May 7 „ 8	VII	Stationary	130	53093·0	2	106186·0	
November 16 „ 21	VIII	1190	160	80425·0	6	482550·0	
December 15 „ 17	IX.	Stationary	150	70686·0	3	212058·0	
15 „ 18	X.	700	150	70686·0	4	282744·0	
Total	10	4390	1600	834409·0	36	3019078·0	

1870								
January	5 to 7	I	Stationary ?	90	25447·0	3	76341·0	The severest cyclones in this year were Nos III X and XI The two latter were typical examples of cyclones Nine cyclones were stationary at least there is no evidence that they travelled to any great extent
	5 " 7	II	480	120	45239·0	3	135717·0	
	29 31	III	480	160	80425·0	3	241275·0	
February	12 13	IV	Stationary ?	140	61575·4	2	123150·8	
	17 21	V	700	100	31416·0	5	157080·0	
	13 18	VI	210	90	25447·0	6	152682·0	
	21 27	VII	460	90	25447·0	7	178129·0	
March	9 11	VIII.	Stationary	90	25447·0	3	76341·0	
April	3 4	IX.		90	25447·0	2	50894·0	
	14 20	X.	810	150	70686·0	7	494802·0	
	12 21	XI	1470	242	183984·7	10	1839847·0	
May	8 10	XII	Stationary	100	31416·0	3	94248·0	
June	2	XIII		90	25447·0	1	25447·0	
November	12	XIV		100	31416·0	1	31416·0	
	28 30	XV		90	25447·0	3	76341·0	
December	1 3	XVI		90	25447·0	3	76341·0	
Total		16	4610	1832	739734·1	62	3830051·8	
1871								
January	4 to 10	I	1040	200	125664·0	7	879648·0	Most of the cyclones of this year were to the east of the meridian of 80° The severest were Nos I II and III Nos. VIII and IX occurred on the same days No XII is remarkable as having taken place in July the conditions under which it was formed are being investigated
	5 10	II.	690	180	101787·8	6	610726·8	
	19 24	III	570	180	101787·8	6	610726·8	
February	21 " 23	IV	280	195	119459·3	3	358377·9	
March	22 " 24	V	360	130	53093·0	3	159279·0	
	26 28	VI	340	130	53093·0	3	159279·0	
April	21 22	VII	Stationary	90	25447·0	2	50894·0	
May	27 29	VIII		140	61575·4	3	184726·2	
		IX		140	61575·4	2	123150·8	
June	1	X		110	38013·4	1	38013·4	
July	8 12	XI	830	160	80425·0	5	402125·0	
November	6 9	XII	600	140	61575·4	4	246301·6	
	28	XIII	Stationary ?	90	25447·0	1	25447·0	
Total		13	4710	1885	908943·5	46	3828695·5	

TABLE I (*continued*)

Date	Number of Cyclone	Distance traversed	Mean Radius	Area πr^2	Duration	Total Cyclonic Area $D-r^2$	Remarks
1872		miles	miles	square miles	days	square miles	
January 29 to Feb 2	I	770	200	125664.0	5	628320.0	
February 5 9	II	850	150	70686.0	5	353430.0	
9 20	III	2470	240	180956.2	12	2171474.4	The cyclones of this year were generally remarkable for their severity, duration and the distances travelled by them. In no year since 18[illegible] did so many violent storms [illegible] place. The severest and longest was No. III.
20 23	IV	390	160	80425.0	4	321700.0	
March 12 13	V	100	180	101787.8	2	203575.6	
14 19	VI	1500	200	125664.0	6	753984.0	
April 2 4	VII	280	170	90792.2	3	272376.6	
15	VIII	Stationary?	100	31416.0	1	31416.0	
May 4 6	IX	920	120	45239.0		135717.0	
20	X	Stationary?	120	45239.0	1	45239.0	
July 12, 14	XI		90	25447.0	3	25447.0	
October 31 Nov 2	XII	340	100	31416.0	3	94248.0	
Total	12	7620	1830	954732.2	45	5036927.6	
1873							
January 6 to 12	I	1180	175	96211.5	7	673480.5	
19 25	II	680	120	45239.0	7	316673.0	
February 2 9	III	1250	200	125664.0	8	1005312.0	
18 23	IV	700	140	61575.4	6	369452.4	
March 8 13	V	815	185	107521.3	6	645127.8	This year also was rather remarkable for its cyclones. The severest were Nos. I, III, and V.
18 21	VI	570	200	125664.0	4	502656.0	
April 17	VII	Stationary	90	25447.0	1	25447.0	
May 5 7	VIII		120	45239.0	3	135717.0	
24 25	IX		90	25447.0	2	50894.0	
October 15	X		100	31416.0	1	31416.0	
November 11	XI		90	25447.0	1	25447.0	
Total	11	5195	1510	714871.2	46	3781622.7	

	1874.							
January	8 to 9	I	Stationary?	90	25447·0	2	50894·0	
	13 „ 18	II	1320	120	45239·0	6	271434·0	
	29 „ 31	III	860	200	125664·0	3	376992·0	
	27	IV	Stationary?	120	45239·0	1	45239·0	
February	19 „ 23	V	660	120	45239·0	5	226195·0	The severest cyclone was No. IX., it passed near Mauritius, and damaged the crops.
March	16 „ 19	VI.	Stationary?	140	61575·4	4	246301·6	
	17 „ 18	VII	„	90	25447·0	2	50894·0	
	16 „ 19	VIII	275	90	25447·0	4	101786·0	
	22 „ 31	IX.	1570	240	180956·2	10	1809562·0	
April	28 „ 30 .	X.	Stationary?	90	25447·0	3	76341·0	
May	7 „ 8	XI	„	120	45239·0	2	90478·0	
December	2 „ 5 .	XII	„	90	25447·0	4	101788·0	
	Total	12	4685	1510	676386·6	46	3447906·6	
	1875							
January	12 to 19	I	600	150	70686·0	7	494802·0	
	12 „ 17 ...	II	380	120	45239·0	6	271434·0	
	25 „ 30	III.	Stationary	150	70686·0	6	424116·0	No great storm took place this year No VIII. was very small, it passed a little south of Mauritius and struck Réunion
	30 , 31 . . .	IV	„	160	80425·0	2	160850·0	
March	6 „ 8	V	390	170	90792·2	3	272376·6	
October	29 .	VI	Stationary	70	15393·8	1	15393·8	
	29 „ 31	VII	„	70	15393·8	3	46181·4	
December	21 „ 22	VIII	400	50	7854·0	2	15708·0	
	Total	8	1770	940	396469·8	30	1700861·8	

TABLE II.—Showing the annual mean Rainfall of various parts of the World, from 1854 to 1872, compared with Wolf's relative numbers of Sun-spot

Years.	Mean rainfall of—					Means.	θ	Variation of rainfall.	Variation of Wolf's sun-spot numbers
	Great Britain.	Continent of Europe	America.	India	Australia &c				
	Thirty stations	Thirty stations	Ten stations	Three stations	Four stations				
	in.	in.	in.	in.	in.	in	in.	in	
1854.	34·73	26·04	39·05	65·67	26·01	38·30			
1855.	27·08	27·23	42·39	45·20	35·81	35·54	36·74	−2·46	−41·0
1856.	34·99	25·08	35·64	58·16	34·09	37·59	36·87	−2·33	−43·7
1857	32·51	19·68	45·99	51·23	34·56	36·79	36·98	−2·22	−26·3
1858.	34·10	22·10	45·99	51·36	30·18	36·75	37·91	−1·29	+ 3·0
1859.	36·96	26·15	47·67	58·43	37·61	41·36	39·89	+0·69	+48·5
1860.	36·12	29·37	37·85	53·09	44·18	40·12	41·48	+2·28	+50·7
1861.	40·71	25·11	42·45	69·00	44·40	44·33	42·38	+3·18	+29·5
1862.	42·68	26·26	44·45	63·46	26·83	40·74	41·35	+2·15	+11·5
1863.	38·22	24·51	44·34	58·76	32·23	39·61	39·21	+0·01	− 3·5
Means...	35·81	25·15	42·58	57·43	34·59	39·11	39·20		. ..
	Forty stations.	Twenty-three stations		Four stations.	Five stations				
1864	33·48	30·14		52·92	27·22	35·94	36·58	−2·60	−15·8
1865	33·14	30·39		54·86	25·55	35·98	36·61	−2·57	−32·2
1866	39·62	31·28		59·16	24·21	38·57	38·01	−1·17	−46·4
1867.	35·79	31·88		53·28	34·80	38·94	39·17	−0·01	−55·4
1868.	39·55	31·14		55·09	35·23	40·25	39·65	+0·47	−25·4
1869.	33·36	29·38		55·28	38·70	39·18	39·54	+0·36	+11·2
1870	26·74	27·48		59·84	44·15	39·55	39·47	+0·29	+76·4
1871.	33·95	29·56		58·36	36·56	39·61	41·08	+1·90	+48·5
1872.	49·04	35·29		60·70	37·25	45·57	42·50	+3·32	+39·0
Means	36·08	30·73	..	56·61	33·74	39·28	39·18		

The comparisons are between the rainfalls at the *same* stations.

The quantities in the column θ are derived from those in the column of *Means* by taking, for example, the mean of the falls in 1854 and 1856 and the mean of that mean and of the fall in 1855, and so on.

First Report of the Committee, consisting of Dr. JOULE, Prof. Sir W. THOMSON, Prof. TAIT, Prof. BALFOUR STEWART, *and* Prof. MAXWELL, *appointed for the purpose of determining the Mechanical Equivalent of Heat.*

WE are able to report that progress has been made with the experiments undertaken by Dr. Joule on behalf of the Committee. Friction of water is the method he has employed, and the average result of upwards of sixty experiments is 773·1 in British gravitation units at Manchester, the greatest deviation from the above average being $\frac{1}{200}$.

Experiments* have yet to be made on the capacity for heat of the brass of which the calorimeter is constructed, which has provisionally been calculated from the results of Regnault for this alloy. The greatest possible error which may have arisen in this way is believed to be $\frac{1}{300}$. Dr. Joule also proposes to compare his mercurial thermometers with the air-thermometer, with a view to obtain accurate boiling-points, and thus correct values of the thermometric scale. The greatest correction which it may be found needful to apply on this account amounts to about $\frac{1}{400}$. These maximum corrections, if taken in the same direction, would necessitate the addition of 4·5 to the equivalent above named.

The experiments made by Hirn on the friction of water have led him to the number 786. But the average of his results, derived from the friction, boring, and crushing of metals, gives 774.

Assuming that the above experiments and those made by Dr. Joule for the Committee on Standards of Electrical Resistance are to be relied on, the unit issued by it would appear to have a resistance too small by $\frac{1}{40}$.

The Committee are happy in being able to state that Professor Maxwell has been working some time with a view to the redetermination of this unit, and that he has also undertaken fresh direct experiments for determining the dynamical equivalent of the thermal unit.

Report of the Committee appointed for the purpose of promoting the extension, improvement, and harmonic analysis of Tidal Observations. Consisting of SIR WILLIAM THOMSON, *LL.D., F.R.S.*, Prof. J. C. ADAMS, *F.R.S.*, J. OLDHAM, WILLIAM PARKES, *M. Inst. C.E.*, and Admiral RICHARDS, *R.N., F.R.S.* *Drawn up by* SIR WILLIAM THOMSON.

SINCE the publication in 1873 of the Committee's Report for 1872, a large amount of work has been gone through in the way of harmonic analysis, exhausting the funds at the disposal of the Committee for this purpose, but none of the results have hitherto been published. They are now offered for publication in this final Report of the Committee, and along with them, by permission of the Council of the Royal Society, some further results obtained by aid of grants of £100 and £50 made by it to Sir W. Thomson out of the Government-Grant Fund for scientific investigation. The work has been all done, as heretofore, for the Committee, under the superintendence of Sir W. Thomson, by Mr Roberts and assistant calculators working under his immediate direction, according to the plans described in the Reports for 1868 and 1869 and summarized in the Report for 1872. The work done for the Committee consists of the full harmonic reduction of:—

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* [These experiments, up to the present date, show a smaller capacity than that anticipated, bringing up the equivalent to 774·1, which will be subject to a small correction, possibly amounting to $\frac{1}{400}$, on account of the thermometric scale error.—*Note*, November 13, 1876.—J. P. J.]

(1) Ten years' observations taken by the self-registering tide-gauge at Helbre Island, at the junction of the Mersey and the Dee.

(2) Two years of Kurrachee, in addition to the three years previously analyzed and published.

(3) Two years' tidal observations by self-registering tide-gauge at San Diego (lat. 32° 42′ N., long. 117° 13′ W.) on the coast of California, and one year's observations at Fort Clinch, Fernandina (30° 43′ N., long. 81° 27′ W.), Florida. The work of the Royal Society consists of full harmonic reductions for three years' observations by self-registering tide-gauge of West Hartlepool, nine months of Port Leopold, 119 days of Beechey Island, one year of Brest, and (a first attack on Mediterranean tides) one year of Toulon.

Helbre Island, 1858 to 1867 inclusive.—The results for Helbre Island have been found from nearly ten years' consecutive observations taken by a self-registering tide-gauge at Great Helbre, about eight miles direct or sixteen miles by water-channels from the tide-gauge at Liverpool, on the St George's landing-stage. Both these tide-gauges are under the charge of Captain Graham H. Hills, R.N., Marine Surveyor to the Board of the Mersey-Dock Estate; and the Committee is indebted to him for the loan of the tide-diagrams from which the present results are obtained. The float of the Helbre Island tide-gauge works in a well, into which the tidal water is admitted by a pipe below low-water level. This connecting pipe is kept free by about once every month closing its mouth, and allowing the water to rush out at low water. The tide-gauge clock is kept accurately to Greenwich mean time by time-signal from Bidstone Observatory. In the years 1860, 1863, and 1864, on account of accidental interruptions, the observations only began on March 1, March 29, and June 3 respectively; in each of the other seven years the observations began on Jan. 1. The results of the harmonic analysis are given in the Tables below. The datum-level from which the mean heights A_0 are calculated is the same as that used for Liverpool, being 12 feet below the level of the "old dock sill."

The results shown in the Tables for the separate years agree fairly well together. For example, the extreme difference for the value between the amplitudes of the solar semidiurnal (R_2 of S) is ·0879 of a foot, or scarcely more than an inch, and the epochs of the same tide 2°·1 of the circle, or 4·2 minutes of time. The amplitude of the mean lunar semidiurnal tide (R_2 of M) varies from year to year, on account of the varying inclination of the moon's orbit to the earth's equator, very nearly in accordance with the equilibrium theory as set forth in Tables II. and II′. (pp. 305 & 307).

The variations which the Tables show in the values of the lunar declinational diurnal tides (R_1 of O) and the lunisolar declinational diurnal and lunisolar declinational semidiurnal (R_1, R_2 of K) are likewise perfectly accounted for.

The following comparison between the evaluated results of the mean solar and mean lunar semidiurnal tides and their overtides, and of the compound Helmholtz lunisolar quarter-diurnal tide of Liverpool and Helbre Island, is exceedingly interesting, and demonstrates the very rapid formation of overtides in channels where the rise and fall is great in comparison with the depth at low water. The results for Liverpool (Report 1872) are the means of seven years' reductions, and for Helbre Island of ten years'. The value of the main tides are approximately equal at both places, the solar and lunar semidiurnal tides at Helbre Island being only about one and two per cent. respectively less than the corresponding tides at St. George's landing-stage at Liverpool.

	S		M.		MS	
	Liverpool ft	Helbre Island ft	Liverpool ft	Helbre Island ft	Liverpool ft	Helbre Island ft
R_2	3 1605	3 1283	10 0259	9 8178		
R_4	0570	0302	6984	4862	4082	2818
R_6			1982	0720		
R_8			0689	0103		

The results for Kurrachee form a continuation of the three years' results included in the Report for 1872 The previous results are given, quoted below from the Report of 1872, along with the new results for the sake of comparison. The results for the whole five years thus now given together agree very fairly with one another, and form a very valuable set of tidal components for this portion of the Indian Ocean

Through the kindness of Professors Peirce and Hilgard, of the United-States Coast Survey, two years' tidal observations taken at San Diego on the coast of California, and one year's observations taken at Fort Clinch, Fernandina, Florida, have been placed at the disposal of the Committee. The harmonic analysis has been completed for these observations, and the results are given below. The Committee are also indebted to the United-States Coast Survey for the observations at Fort Point, California, and Cat Island, Gulf of Mexico, of which the harmonic reductions were published in the Report for 1872. These results also are repeated in the present Report, as well as those for Kurrachee, for the sake of comparison.

The agreement of results for the two years for San Diego is exceptionally good throughout. There is a remarkable disproportion between the values of the smaller and larger elliptic semidiurnal tides (R_2 of I and N) The equilibrium-theoretical proportion between these components is about as 1 to 7, but the proportion here is (mean of two years) about as 1 to 35 The smaller component is exceptionally small.

The retardation of phase of spring-tides (0 030 day) is less than that determined for Fort Point, San Francisco Bay, and is the smallest value yet found for any port

One of the chief points of interest in the results for Fort Clinch is the remarkable disproportion between the mean solar and the mean lunar semidiurnal tides, which is as 1 to 6 very nearly. The equilibrium-theoretical proportion being about as 1 to 2 1. This is very nearly fulfilled between the solar and lunar diurnal tides (R_1 of P and O). The time of the coincidence of phase of the P and O declinational diurnal tides is here *negative* This is the first instance yet found of the coincidence happening *before* the times of New and Full Moon.

Among the most interesting results found by the reduction of the tides of these two places, is that at San Diego the proportion between the two chief tides is nearly identical with what the equilibrium-theory gives, namely, about 2·1 to 1, while (as said above) the proportion between them at Fort Clinch is about as 6 to 1, or the ratio of the solar tide to the lunar tide is only one third of the value which the equilibrium theory assigns to it.

Helbre Island (Lat. 53° 24′ N., Long. 12^m W. from Greenwich)

		1858.	1859	1860.	1861	1862	1863.	1864	1865	1866	1867.
		ft	ft	ft	ft	ft	ft	ft	ft	ft	ft
	A_0	16·2778	16·4127	16·4489	16·4785	16·6454	16·4485	16·3848	16·4154	16·5269	16·4185
	I*	28°·3	27°·6	26°·6	25°·2	23°·6	21°·9	20°·3	19°·1	18°·5	18°·6
S Speed of Semidiurnal $2(\gamma-\eta)$	R_2	3·1380	3·1769	3·1625	3·1711	3·1186	3·1204	3·0890	3·0929	3·1058	3·1080
	ϵ_2	2°·07	3°·19	2°·05	2°·21	2°·84	2°·58	3°·39	3°·44	1°·34	2°·06
	R_4	0·0329	0·0330	0·0264	0·0301	0·0261	0·0254	0·0347	0·0286	0·0304	0·0343
	ϵ_4	321°·59	329°·48	298°·35	332°·45	317°·34	299°·95	309°·43	302°·85	303°·82	301°·87
M. Speed of Semidiurnal $2(\gamma-\sigma)$.	R_1	0·0094	0·0770	0·0795	0·0424	0·0839	0·0160	0·0039	0·0535	0·0509	0·0370
	ϵ_1	291°·34	305°·89	19°·17	306°·84	322°·84	35°·68	265°·86	336°·40	32°·18	286°·17
	R_2	9·4290	9·4793	9·7248	9·7401	9·7786	9·8668	9·9880	10·0951	10·0711	10·0049
	ϵ_2	318°·82	318°·29	317°·11	316°·34	317°·62	317°·72	319°·03	319°·09	318°·91	319°·65
	R_3	0·0985	0·0874	0·1026	0·1376	0·0786	0·1195	0·1079	0·0806	0·1130	0·1161
	ϵ_3	303°·47	286°·03	304°·03	275°·06	280°·17	276°·18	302°·69	283°·40	309°·79	293°·57
	R_4	0·4151	0·4164	0·4721	0·4709	0·4116	0·5156	0·5432	0·5452	0·5409	0·5308
	ϵ_4	214°·95	216°·20	210°·36	206°·32	213°·99	209°·43	209°·89	209°·05	208°·08	211°·57
	R_6	0·0576	0·0578	0·0761	0·0644	0·0660	0·0693	0·0843	0·0761	0·0884	0·0796
	ϵ_6	34°·87	46°·96	20°·81	15°·18	22°·05	29°·71	39°·03	39°·06	30°·96	29°·25
	R_8	0·0105	0·0059	0·0105	0·0130	0·0107	0·0136	0·0118	0·0098	0·0109	0·0063
	ϵ_8	347°·20	46°·04	331°·79	357°·42	300°·59	5°·39	11°·45	344°·24	305°·69	339°·31

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* I is the average inclination of the Moon's orbit to the equator, or her mean maximum north or south declination, for the year.

MS. Speed $(4\gamma-2\sigma-2\eta)$	R_4	0·2646	0·2000	0·2560	0·3065	0·2581	0·2740	0·3218	0·3329	0·3006	0·3030
	ϵ_4	275°·25	263°·59	269°·87	264°·62	274°·73	264°·00	264°·84	262°·77	260°·69	260°·57
2SM. Speed $2(\gamma+\sigma-2\eta)$	R_2	0·1268	0·1177	0·1196	0·1250	0·1271	0·1247	0·0973	0·1277	0·1083	0·1164
	ϵ_2	217°·73	231°·24	238°·33	209°·63	218°·36	235°·92	213°·49	211°·03	221°·36	229°·60
K. Speeds γ and 2γ	R_1	0·4291	0·4124	0·4025	0·4198	0·3886	0·3742	0·3601	0·3726	0·3697	0·3273
	ϵ_1	279°·48	272°·67	268°·74	269°·28	268°·85	270°·22	272°·39	274°·90	274°·08	279°·20
	R_2	1·2010	1·1064	1·0831	0·9952	0·9173	0·8870	0·6074	0·7104	0·6876	0·5800
	ϵ_2	352°·53	344°·85	339°·76	344°·22	336°·47	348°·07	346°·36	355°·23	349°·55	1°·22
O Speed $(\gamma-2\sigma)$	R_1	0·4310	0·4245	0·4034	0·4301	0·3812	0·3552	0·2995	0·3214	0·2932	0·2902
	ϵ_1	314°·15	317°·22	320°·18	321°·77	324°·92	320°·41	316°·43	316°·94	311°·78	306°·02
P Speed $(\gamma-2\eta)$	R_1	0·1720	0·1469	0·1305	0·1310	0·1617	0·1379	0·1336	0·1530	0·1596	0·1342
	ϵ_1	94°·37	90°·26	100°·41	91°·04	86°·25	103°·55	86°·09	88°·79	88°·79	93°·36
L. Speed $(2\gamma-\sigma-\varpi)$.	R_2	0·4740	0·5610	0·2713	0·3919	0·2639	0·3516	0·4373	0·4869	0·4220	0·5554
	ϵ_2	154°·17	153°·41	150°·58	158°·95	77°·95	161°·50	166°·21	167°·03	144°·91	161°·38
N. Speed $(2\gamma-3\sigma+\varpi)$	R_2	1·7914	1·8407	1·7567	1·8658	1·8537	1·8726	1·9744	1·9146	1·8916	1·9184
	ϵ_2	295°·19	291°·16	289°·23	292°·69	294°·48	294°·15	294°·61	294°·09	297°·51	297°·16
λ. Speed $(2\gamma-\sigma+\varpi-2\eta)$	R_2	0·1392	0·1980	0·0571	0·2002	0·2555	0·1847	0·2816	0·2721	0·2635	0·1103
	ϵ_2	146°·72	111°·20	192°·31	170°·45	174°·73	140°·66	152°·22	162°·09	162°·31	110°·39
ν Speed $(2\gamma-3\sigma-\varpi+2\eta)$	R_2	0·1820	0·3121	0·2161	0·6202	0·3716	0·6211	0·6843	0·7056	0·5415	0·1792
	ϵ_2	267°·02	272°·92	334°·26	275°·19	208°·23	273°·60	287°·13	293°·61	262°·74	291°·51

Helbre Island (*continued*)

		1858	1859	1860.	1861	1862.	1863	1864	1865.	1866	1867
		ft	ft	ft	ft.	ft	ft	ft	ft	ft	ft
μ. Speed $2(\gamma-2\sigma+\eta)$.	R_2	0·0314	0·1659	0·0726	0·1423	0·0259	0·0590	0·0640	0·1024	0·0126	0·1615
	ϵ_2	78° 35	40° 91	26° 48	28° 21	341° 11	69° 30	[illegible]° 80	41° 40	330° 25	67° 00

		1858.	1859.	1866	1867			1858	1859	1866	1867
J Speed $(\gamma+\sigma-\varpi)$	R_1	0·0245	0·0211	0·0147	0·0374	Q Speed $(\gamma-3\sigma+\varpi)$	R_1	0·1270	0·1140	0·0975	0·0991
	ϵ_1	337° 75	242° 07	69°·60	191° 50		ϵ_1	271° 34	249° 25	250° 87	256° 62

		1858 and 1859	1860 and 1861	1864 and 1865	1866 and 1867
R. Speed $(2\gamma-\eta)$	R_2	0·0215	0·1017	0·0501	0·0258
	ϵ_2	118° 08	31° 73	85° 12	164° 13
T Speed $(2\gamma-3\eta)$.	R_2	0·2216	0·4055	0·2295	0·1576
	ϵ_2	30° 14	85° 05	75° 40	356° 36

Coincidence of phase of S and M.	Coincidence of phase of P and O.	Coincidence of phase of M and N	Opposition of phase of L and M
1·815 days	5·550 days	1·855 days	0·869 day
After New or Full Moon.		After Moon's Perigee	

Results deduced from mean of 10 years' observations

Fort Clinch, Fernandina Har., Florida (Lat 30° 42 N, Long 81° 27 W)

Year 1860 61 $A_0 = 6\ 4451$ ft I = 26° 6

	S	M	K	O	P	J	Q
Speed	$2(\gamma-\eta)$	$2(\gamma-\sigma)$	(2γ)	$(\gamma-2\sigma)$	$(\gamma-2\eta)$	$(\gamma+\sigma-\varpi)$	$(\gamma-3\sigma+\varpi)$
	ft	ft	ft	ft	ft	ft	ft
R_1	0 0724	0 0282	0 3606	0 2753	0 1170	0 0375	0 0627
ϵ	91° 90	25° 73	204° 38	42° 42	25° 10	239° 35	47° 77
R_2	0 4745	2 8338	0 1414				
ϵ_2	252° 09	221° 11	234° 10				
R_3		0 0341					
ϵ_3		277° 83					
R_4	0 0234	0 0576					
ϵ_4	12° 85	55° 14					
R_6		0 0362					
ϵ_6		359° 67					
R_8		0 0103					
ϵ_8		315° 92					

	L	N	λ	ν	μ
	$(2\gamma-\sigma-\varpi)$	$(2\gamma-3\sigma+\varpi)$	$(2\gamma-\sigma+\varpi-2\eta)$	$(2\gamma-3\sigma-\varpi-2\eta)$	$(2\gamma-3\sigma\ \ \varpi+2\eta)$
R_2	0 0969	0 6843	0 1073	0 1474	0 0992
ϵ_2	36° 24	206° 19	316° 86	215° 02	241° 25

Coincidence of phase of S and M	Coincidence of phase of P and O	Coincidence of phase of M and N	Opposition of phase of L and M
1 271 days	−0 710 of a day	1 142 days	−0 378 of a day
After New or Full Moon		After Moon's Perigee	

San Diego, California (Lat 32° 42 N, Long 117° 13 W)

	S Speed $2(\gamma-\eta)$		M Speed $2(\gamma-\sigma)$		MS Speed $(4\gamma-2\sigma-2\eta)$	
	1860	1861	1860	1861	1860	1861
	ft	ft				
A_0	5 9089	5 7864	I= 26° 6	25° 2	ft	ft
R_1	0 0303	0 0249	0 1026	0 0918		
ϵ_1	228° 90	246° 32	25° 81	344° 96		
R_2	0 6969	0 6934	1 6827	1 6974		
ϵ_2	273° 33	275° 42	272° 75	274° 52		
R_3			0 0074	0 0071		
ϵ_3			14° 69	18° 02		
R_4	0 0066	0 0052	0 0268	0 0267	0 0061	0 0124
ϵ_4	186° 91	221° 08	201° 62	195° 99	186° 12	188° 90
R_6			0 0092	0 0129		
ϵ_6			82° 28	73 28		

	K Speed (2γ)		O Speed $(\gamma-2\sigma)$		P Speed $(\gamma-2\eta)$	
	1860	1861	1860	1861	1860	1861
R_1	1 1760	1 1386	0 7749	0 7426	0 3515	0 3612
ϵ_1	176° 69	176° 45	354° 74	358° 03	0° 70	359° 81
R_2	0 2469	0 2197				
ϵ_2	246° 06	249° 74				

	J Speed ($\gamma+\nu-\varpi$)		Q Speed ($\gamma-3\sigma-\varpi$)	
	1860	1861	1860	1861
R_1	0 0752	0 1067	0 1440	0 1698
ϵ_1	176° 40	180° 80	351° 09	356° 33

	L Speed ($2\gamma-\sigma-\varpi$)		N Speed ($2\gamma-3\sigma+\varpi$)		λ. Speed ($2\gamma-\sigma+\varpi+2\eta$).	
	1860	1861	1860	1861	1860	1861
R_2	0 0191	0 0052	0 4060	0 4363	0 0678	0 0486
ϵ_2	174° 64	163° 62	255° 99	259° 14	357° 65	85° 64

ν Speed ($2\gamma-3\sigma-\varpi+2\eta$)		μ Speed ($2\gamma-2\sigma+\eta$)	
1860	1861	1860	1861.
0 1309	0 0687	0 0373	0 0150
258° 76	230° 96	240° 68	230° 74

	R Speed ($2\gamma-\eta$)	T Speed ($2\gamma-3\eta$)
	1860 and 1861	1860 and 1861
R_2	0 0104	0 0408
ϵ_2	253° 14	38° 12

Coincidence of phase of		Coincidence of	Opposition of
S and M	P and O	phase of M and N	phase of L and M
0·030 of a day	0 159 of a day	1 230 days	5 711 days
After New or Full Moon		After Moon's Perigee.	
Deduced from mean values for 2 years			

A series of tide-observations extending through five years, commencing 1868, May 1, taken by the Manora self-registering tide-gauge at Kurrachee, were also kindly lent by Mr. Parkes for the purpose of reduction. The following series have been analyzed for each year separately, with the exception of the solar semidiurnal tide-components R and T, for which it is necessary to combine the observations extending through two entire years. The datum-line is 2 feet *below* the datum-line of the diagram-sheets.

Kurrachee (Lat. 24° 53′ N., Long. 4h 28m E. of Greenwich).

Year	1868–69	1869–70	1870–71	1871–72	1872–73
	ft	ft	ft.	ft	ft.
A_0 =	7 1488	7 2908	7 2644	7 1068	7 0510
I =	19° 6	21° 2	23° 0	24° 6	26° 2

	S. Speed of semidiurnal $2(\gamma-\eta)$				
	1868–69	1869–70	1870–71.	1871–72	1872–73
R_1	0 0718	0 0712	0 0750	0 0829	0 1082
ϵ_1	176° 57	187° 50	162° 29	158° 20	147° 41
R_2	0 9323	0 9425	0 9230	0 9512	0 9515
ϵ_2	322° 72	323° 68	323° 68	321° 94	321° 56
R_4	very small	very small	0 0141	0 0126	0 0083
ϵ_4			355° 95	4° 54	0° 00
R_6		. .	...	0 0036	0 0117
ϵ_6	.	.		292° 99	295° 25

M Speed of semidiurnal $2(\gamma-\sigma)$

	1868-69	1869-70	1870-71	1871-72	1872-73
R_1	0 018		0 0510	0 0712	0 0565
ϵ_1	271° 60		329° 18	229° 28	131° 25
R_2	2 5859	2 4974	2 4717	2 4822	2 4374
ϵ_2	295° 78	297° 24	296° 62	295° 66	295° 66
R_3	0 0439	0 0382	0 0492	0 0477	0 0355
ϵ_3	335° 18	336° 09	325° 46	335° 54	319° 15
R_4	0 0169	0 0284	0 0242	0 0294	0 0191
ϵ_4	47° 04	30° 41	31° 70	27° 11	32° 19
R_6	0 0444	0 0494	0 0445	0 0445	0 0444
ϵ	225 91	215° 16	224° 55	209° 56	219° 89
R_8				0 0062	0 0058
ϵ_8				257° 37	273° 49

K Speed of semidiurnal (2γ)

	1868-69	1869-70	1870-71	1871-72	1872-73
R_1	1 1669	1 1907	1 2392	1 3128	1 3523
ϵ_1	142° 87	144° 73	146° 87	145° 04	143° 43
R_2	0 2389	0 2355	0 2467	0 3072	0 3339
ϵ_2	340° 25	330° 57	330° 94	338° 16	336° 57

O Speed $(\gamma-2\sigma)$

	1868-69	1869-70	1870-71	1871-72	1872-73
R_1	0 5688	0 5905	0 6164	0 6633	0 6927
ϵ_1	308° 87	309° 94	306° 97	307° 07	307° 12

P Speed $(\gamma-2\eta)$

	1868-69	1869-70	1870-71	1871-72	1872-73
R_1	0 3755	0 3850	0 3746	0 3598	0 3678
ϵ_1	316° 35	320° 27	314° 97	317° 91	317° 44

J Speed $(\gamma+\sigma-\varpi)$

	1868-69	1869-70	1870-71	1871-72	1872-73
R_1	0 0800	0 0434	0 0686	0 1123	0 1138
ϵ_1	178° 58	165° 88	141° 37	163° 56	182° 81

Q Speed $(\gamma-3\sigma+\varpi)$

	1868-69	1869-70	1870-71	1871-72	1872-73
R_1	0 1110	0 1100	0 1354	0 1515	0 1411
ϵ_1	308° 23	320° 34	313° 05	309° 98	313° 54

L Speed $(2\gamma-\sigma-\varpi)$

	1868-69	1869-70	1870-71	1871-72	1872-73
R_2	0 0804	0 0365	0 0824	0 0519	0 1561
ϵ_2	108° 67	140° 69	129° 68	184° 24	72° 06

N Speed $(2\gamma-3\sigma+\varpi)$

	1868-69	1869-70	1870-71	1871-72	1872-73
R_2	0 6221	0 5987	0 5766	0 6473	0 5947
ϵ_2	280° 31	282° 83	281° 35	281° 96	276° 79

λ. Speed $(2\gamma-\sigma+\varpi-2\eta)$

	1868–69	1869–70	1870–71.	1871–72	1872–73
R_2	0·0613	0·0381	0·0432	0·0839	0·0750
ϵ_2	156°·46	91°·56	30°·71	29°·40	194°·00

ν. Speed $(2\gamma-3\sigma-\varpi+2\eta)$

	1868–69	1869–70	1870–71	1871–72	1872–73
R_2	0·1955	0·0832	0·0814	0·1415	0·1881
ϵ_2	255°·63	224°·40	345°·20	285°·98	302°·03

μ Speed $(2\gamma-4\sigma+2\eta)$

	1868–69	1869–70.	1870–71	1871–72	1872–73
R_2	0·0703	0·0333	0·0714	0·0617	0·0534
ϵ_2	269°·99	227°·72	304°·53	258°·49	273°·84

MS Speed $(4\gamma-2\sigma-2\eta)$

	1868–69.	1869–70	1870–71	1871–72
R_4	0·0173	0·0236	0·0311	0·0195
ϵ_4	216°·79	181°·30	326°·55	0°·05

R Speed $(2\gamma-\eta)$

	1868–69 and 1869–70.	1870–71 and 1871–72
R_2	0·0353	0·0272
ϵ_2	12°·04	321°·23

T Speed $(2\gamma-3\eta)$

	1868–69 and 1869–70	1870–71 and 1871–72
R_2	0·1108	0·0576
ϵ_2	38°·96	101°·70

Long-period Tides.

	1868–69 ft.	1869–70 ft	1870–71. ft	
R	0·115	0·179	0·162	Solar annual (elliptic) tide Speed (η).
ε	43°·96	80°·20	107°·11	
R	0·198	0·059	0·062	Solar semiannual (declinational) tide.
ε	81°·98	116°·93	69°·69	Speed (2η).
R	0·076	0·043	0·032	Lunar monthly (elliptic) tide.
ε	247°·73	175°·27	115°·90	Speed $(\sigma-\varpi)$
R	0·038	0·064	0·035	Lunar fortnightly (declinational) tide.
ε	335°·40	333°·91	283°·22	Speed (2σ)
R	0·009	0·075	0·058	Lunisolar synodic fortnightly (shallow-water)
ε	326°·19	16°·98	156°·62	tide. Speed $2(\sigma-\eta)$

Three years' tidal observations, taken at Fort Point (lat. 37° 40′ N., long. $8^h\,9^m$ W. of Greenwich), San Francisco Bay, California, were received and analyzed, with the following results:—

Year	1858–59.	1859–60.	1860–61.
	ft.	ft.	ft.
$A_0=$	8·7103	8·2651	8·1608
$I=$	28°·0	26°·9	25°·4

S. Speed of semidiurnal $2(\gamma-\eta)$.

	1858-59	1859-60	1860-61
R_1	0·0146	very small.	very small
ϵ_1	211°·96	...	...
R_2	0·4067	0·3802	0·3824
ϵ_2	334°·24	335°·80	336°·45
R_3		...	
ϵ_3			
R_4	very small	very small	very small
ϵ_4			...

M Speed of semidiurnal $2(\gamma-\sigma)$

	1858-59	1859-60	1860-61.
R_1	0·0539	0·0808	0·0863
ϵ_1	46°·30	189°·37	32°·71
R_2	1·6694	1·6215	1·6645
ϵ_2	330°·81	331°·30	328°·72
R_3	very small	very small.	very small.
ϵ_3	...	...	
R_4	0·0616	0·0712	0·0698
ϵ_4	23°·32	26°·73	11°·15

MS Speed $(4\gamma-2\sigma-2\eta)$

	1858-59	1859-60.	1860-61
R_4	0·0248	0·0325	0·0315
ϵ_4	22°·33	12°·25	22°·81

μ. Speed $2(\gamma-2\sigma+\eta)$.

	1858-59.	1859-60	1860-61
R_2	0·0257	0·0311	0·0252
ϵ_2	254°·34	206°·14	209°·53

K Speed of semidiurnal (2γ)

	1858-59	1859-60	1860-61
R_1	1·3370	1·3036	1·2925
ϵ_1	192°·17	190°·88	188°·55
R_2	0·1759	0·1716	0·1351
ϵ_2	326°·65	314°·53	308°·75

O Speed $(\gamma-2\sigma)$

	1858-59	1859-60	1860-61
R_1	0·8917	0·8511	0·8784
ϵ_1	3°·39	6°·25	4°·01

P Speed $(\gamma-2\eta)$

	1858-59.	1859-60	1860-61
R_1	0·3672	0·3659	0·3869
ϵ_1	16°·52	15°·90	13°·52

L Speed $(2\gamma-\sigma-\varpi)$.

	1858-59.	1859-60	1860-61
R_2	0·0591	0·0370	0·0506
ϵ_2	102°·63	183°·00	170°·16

N Speed $(2\gamma-3\sigma+\varpi)$.

	1858-59	1859-60	1860-61
R_2	0·3931	0·3494	0·3545
ϵ_2	303°·46	305°·53	302°·51

R Speed $(2\gamma-\eta)$

	1858-59 and 1859-60
R_2	0·0076
ϵ_2	164°·00

T Speed $(2\gamma-3\eta)$

	1858-59 and 1859-60
R_2	0·0142
ϵ_2	277°·90

λ. Speed $(2\gamma-\sigma+\varpi-2\eta)$

	1858-59	1859-60	1860-61
R_2	0·0372	0·0275	0·0121
ϵ_2	188°·30	156°·39	144°·18

ν Speed $(2\gamma-3\sigma-\varpi+2\eta)$

	1858-59	1859-60	1860-61.
R_2	0·1044	0·0387	0·0437
ϵ_2	287°·23	272°·46	349°·59

J. Speed $(\gamma+\sigma-\varpi)$.

	1858-59	1859-60	1860-61
R_1	0·0819	0·0376	0·0565
ϵ_1	213°·98	208°·29	183°·40

Q. Speed $(\gamma-3\sigma+\varpi)$

	1858-59	1859-60	1860-61.
R_1	0·1706	0·1056	0·1332
ϵ_1	353°·03	331°·34	8°·93

Coincidence of phase of S and M.	Coincidence of phase of P and O.	Coincidence of phase of M and N.	Opposition of phase of L and M.
0·214 of a day	0·441 of a day	2·024 days	0·126 of a day
After New and Full Moon		After Moon's perigees	

Remark an abrupt diminution in the height of mean level after the first two years, which the following extract from a letter received from Prof. J. E Hilgard fully explains :—

"The change in the mean-level reading at Fort Point is a matter of much "annoyance to us The tide-gauge was put up in a small building near the "end of a wharf, and the tide-staff used for comparison was close to it. "Now it was observed after the observations had continued some time that "the wharf was settling, at least the part where the gauge stood Then "the gauge was moved to a point a little nearer to the shore believed to be "firm; but we think the whole wharf settled and continued to do so for years. "There seems to be a bog-formation underlying the surface deposit at that "place. There is probably no way of ascertaining the amount of settling "except from the observations themselves. We are now having frequent "levellings made, referring the tide-staff to a rocky ledge further inland"

Cat Island, Gulf of Mexico (Lat. 30° 23′ N , Long 5^h 56^m W of Greenwich).

The following results represent the tide-components as far as they have at present been evaluated. *Datum* 10 feet *below* datum of United-States Coast Survey —

Year 1848 $A_0=4$ 8574 ft $I=18°$ 45.

	S	M	L	N
Speed	$2(\gamma-\eta)$	$2(\gamma-\sigma)$	$2(\gamma-\frac{1}{2}\sigma-\frac{1}{2}\varpi)$	$2(\gamma-\frac{3}{2}\sigma+\frac{1}{2}\varpi)$
R_1	0 0442	0 0101		
ϵ_1	10° 04	95° 21		
R_2	0 0677	0 1195	0 0118	0 0269
ϵ_2	23° 80	10° 75	222° 40	33° 57

	K	O	P	J	Q
Speed	$2(\gamma)$	$(\gamma-2\sigma)$	$(\gamma-2\eta)$	$(\gamma+\sigma-\varpi)$	$(\gamma-3\sigma+\varpi)$
R_1	0 4627	0 3855	0 1559	0 0292	0 0733
ϵ_1	55° 20	224° 29	230° 65	28° 22	215° 32
R_2	0 0205			....	...
ϵ_2	288° 73			......	.....

It is extremely interesting to find that, although the lunar and solar semidiurnal tides are very small in value, the series of means from which they were obtained being extremely regular and good, the consequent determination of the phase of spring-tides from their respective epochs is probably correct within a few minutes. The proportion between the amplitudes of the lunar and solar semidiurnal tides is the nearest approach to equality yet obtained, being in the ratio of 11 to 6. The comparatively large value of R_1 of Series S is undoubtedly a genuine tide; but the smallness of the corresponding value of Series M must forbid the conclusion of its being purely astronomical. It is perhaps produced by temperature or wind, its time of maximum being about 40 minutes after noon. There are also indications of a similar and large annual tide of 0·274 foot amplitude, and maximum about Aug 16, which is also probably meteorological in its origin. The proportion between the lunar and solar diurnal (Declinational) tides (R_1 of Series O and P) will be, on the assumption of the variation of R_1 of Series O being as the square of the sine of the declination, about 4 to 1.

The following are the values of the long-period tides :—

	R	e
	ft	°
Solar annual tide (elliptic and meteorological) .	0 274	144 50
Solar semiannual tide (declinational and meteorological)	0 128	35 02
Lunar monthly tide (elliptic) .	0 106	304 17
Lunar fortnightly tide (declinational)	0 043	136 69
Lunisolar fortnightly tide (synodic)	0 099	336 26

The results of three years tide observations taken at West Hartlepool England (Lat 54° 41 N Long 1° 12 W), by a self registering tide gauge, from 1858, July 1, to 1861, July 5 —

	Year	1858-59	1859-60	1860-61
Inclination of Lunar orbit to Earth's equator	$I =$	28° 0	27° 1	25° 9
		ft	ft.	ft
Mean sea level above datum 12 feet below mean level of diagrams	$A_0 =$	12 1518	11 9706	12 0056

S Speed of semidiurnal $2(\gamma-\eta)$

	1858-59	1859-60	1860-61
R_1	0 0192	0 0542	0 0248
ϵ_1	131° 83	156° 75	168° 83
R_2	1 7543	1 7107	1 7492
ϵ_2	140° 50	138° 09	137° 87
R_4	0 0253	0 0212	0 0190
ϵ_4	190° 24	173° 78	171° 53

M Speed of semidiurnal $2(\gamma-\sigma)$

	1858-59	1859-60	1860-61
R_1	0 0376	0 0635	0 0397
ϵ_1	1° 71	47° 57	46° 87
R_2	5 0062	5 0181	5 0901
ϵ_2	97° 50	97° 17	94° 58
R_3	0 0358	0 0217	0 0453
ϵ_3	120° 01	103° 12	124° 15
R_4	0 0746	0 1006	0 0958
ϵ_4	100° 63	113° 91	102° 64
R_6	0 0643	0 0716	0 0704
ϵ_6	47° 10	50° 11	40° 08

K Speed of semidiurnal (2γ)

	1858-59	1859-60	1860-61
R	0 4298	0 3961	0 4065
ϵ	333° 63	331° 54	330° 61
R_2	0 6218	0 6225	0 5298
ϵ_2	131° 36	123° 21	116° 02

O Speed $(\gamma-2\sigma)$

	1858-59	1859-60	1860-61
R_1	0 5054	0 4829	0 4854
ϵ_1	357° 96	2° 36	4° 29

P Speed $(\gamma-2\eta)$

	1858-59	1859-60	1860-61
R_1	0 1211	0 1202	0 0946
ϵ_1	142° 42	142° 44	142° 24

J Speed $(\gamma+\sigma-\varpi)$

	1858-59	1859-60	1860-61
R	0 0364	0 0291	0 0291
ϵ_1	353° 36	21° 81	183° 65

Q Speed $(\gamma-3\sigma+\varpi)$

	1858-59	1859-60	1860-61
R	0 1632	0 1630	0 1751
ϵ_1	315° 54	307° 45	303° 77

L Speed $(2\gamma-\sigma-\varpi)$

	1858-59	1859-60	1860-61
R_2	0 2040	0 1308	0 1721
ϵ_2	274° 47	298° 70	286° 19

N Speed $(2\gamma-3\sigma+\varpi)$

	1858-59	1859-60	1860-61
R_2	0 9195	0 9480	1 0251
ϵ_2	76° 19	68° 90	70° 10

λ Speed $(2\gamma-\sigma+\varpi-2\eta)$

	1858-59	1859-60	1860-61.
R_2	0 0554	0 1068	0 1153
ϵ_2	326° 80	262° 93	293° 03

ν Speed $(2\gamma-3\sigma-\varpi+2\eta)$

	1858-59	1859-60	1860-61
R_2	0 1110	0 3170	0 3639
ϵ_2	74° 42	114° 12	71° 27

μ Speed $2(\gamma-2\sigma+\eta)$.

	1858-59	1859-60	1860-61.
R_2	0·0907	0·0951	0·0549
ϵ_2	6°·57	342°·40	20°·10

MS Speed $(4\gamma-2\sigma-2\eta)$

	1858-59	1859-60	1860-61
R_4	0·0454	0·0388	0·0447
ϵ_4	121°·48	140°·42	112°·73

2SM Speed $(2\gamma+2\sigma-4\eta)$.

	1858-59	1859-60	1860-61
R_2	0·0326	0·0332	0·0087
ϵ_2	315°·68	30°·19	227°·66

R. Speed $(2\gamma-\eta)$

	1859-60 and 1860-61.
R_2	0·0082
ϵ_2	258°·78

T Speed $(2\gamma-3\eta)$

	1859-60 and 1860-61
R_2	0·1403
ϵ_2	279°·83

Long-period Tides.

Speed		σ.	2σ	$2(\sigma-\eta)$.	η.	2η.
		ft	ft	ft	ft	ft.
1858-59.	R	0·075	0·052	0·131	0·217	0·004
	ϵ	23°·53	190°·34	70°·88	257°·63	275°·40
1859-60	R	0·135	0·053	0·131	0·366	0·138
	ϵ	175°·75	222°·34	57°·35	200°·02	105°·65
1860-61	R	0·139	0·073	0·141	0·213	0·149
	ϵ	79°·19	158°·62	54°·55	199°·69	286°·62

(From mean of 3 years.)

	days	
Coincidence of phase of S and M ...	= 1·7391	After New or Full Moon
Coincidence of phase of P and O ..	= 5·7762	
Coincidence of phase of M and N ..	= 1·8898	After moon's perigee
Opposition of phase of L and M	= 0·7677	

The results of the three years' reductions agree, on the whole, well together. The following small components, however, are somewhat discordant, viz. the elliptic diurnal tide J, the smaller component of the *evection* semidiurnal tide λ, and the lunisolar compound semidiurnal tide 2SM.

The good agreement between the separate determinations of the mean sea-level renders Hartlepool a favourable place for the purposes of trigonometrical survey, the annual tide also being much less in amount than at Liverpool, to the mean sea-level of which the present survey of the United Kingdom is referred.

The values of the diurnal components are as large as those for Liverpool, where the mean solar and lunar semidiurnal tides are nearly double the values of those for Hartlepool, and are the largest yet evaluated for English ports.

The value of the smaller elliptic semidiurnal tide (L) agrees very nearly with the equilibrium-theory value of the values of this component for other English ports, being considerably in excess of the theoretically assigned value. The larger component (N) agrees exactly with that deduced from theory.

A remarkable point in the deductions is the smallness of the overtides of the chief semidiurnal tides, and also of the compound lunisolar quarter-diurnal tide (MS), which have been well marked in the other English ports of which the observations have been analyzed.

There is scarcely sufficient agreement between the results deduced from the long-period tides to be satisfactory although the quantities of some are within reasonable limits The values for η as usual show an undoubtedly genuine annual tide of about three inches with its maximum about the end of October or beginning of November which agrees with the time given for other English ports Of the other long period tides the synodic fortnightly $[2(\sigma-\eta)]$ gives a fair agreement between the values deduced from the separate years

Results of Hourly Tide observations taken at Port Leopold, Arctic Archipelago by Sir James Clark Ross from 1848 Nov 1, to 1849, July 31 (Lat 74° N Long 91° W)

I or inclination of moon's orbit to earth's equator = 18° 7

Speed	S $2(\gamma-\eta)$ ft	M $2(\gamma-\sigma)$ ft	I $(2\gamma-\sigma-\varpi)$ ft	N $(2\gamma-3\sigma+\varpi)$ ft	K (2γ) ft
R	0 0308	0 0441			0 7997
ϵ_1	26° 55	269° 19			309° 62
R_2	0 6432	2 0736	0 0513	0 4345	0 1325
ϵ_2	28° 78	338° 88	189° 18	306° 36	34° 99
R_4	0 0065	0 0160			
ϵ_4	256° 84	203° 03			

Speed	O $(\gamma-2\sigma)$	P $(\gamma-2\eta)$
R	0 3632	0 2161
ϵ	69° 64	127° 55

	days	
Coincidence of phase of S and M	= 2 0467	After New or Full Moon
Coincidence of phase of P and O	= 2 3752	
Coincidence of phase of M and N	= 2 4891	After moon's perigees
Opposition of phase of L and M	= 2 3192	

Results of Hourly Tide observations taken at Beechey Island Erebus Bay Arctic Archipelago by Captain Pullen for 119 days commencing 1858, Nov 2 (Lat 74° 43 N Long 91° 54 W)

I or inclination of moon's orbit to earth's equator = 28° 0

Speed	S $2(\gamma-\eta)$ ft	M $2(\gamma-\sigma)$ ft	L $(2\gamma-\sigma-\varpi)$ ft	N $(2\gamma-3\sigma+\varpi)$ ft
R_2	0 686	1 930	0 0867	0 4149
ϵ_2	33° 71	345° 92	209° 01	313° 51
R_4	very small	0 022		
ϵ_4		265° 83		

Speed	K $2(\gamma)$	O $(\gamma-2\sigma)$	P $(\gamma-2\eta)$
R_1	0 9930	0 570	0 2150
ϵ_1	329° 15	75° 84	132° 11
R_2	0 1944		
ϵ_2	46° 65		

	days.	
Coincidence of phase of S and M	= 1 9601	After New or Full Moon
Coincidence of phase of P and O	= 2 3080	
Coincidence of phase of M and N	= 2 4807	After moon's perigees
Opposition of phase of L and M	= 3 2981	

The tides at Port Leopold and at Beechey Island, as seen from the above analyzed constituents (due allowance being given to the different values for I), are almost identical in character, the agreements of the components when compared being remarkably close.

The diurnal components are large, and in the years of maximum declination of moon nearly sufficient at certain parts of the lunation to reduce the period of the tide to that of one tide only in the twenty-four hours.

The narrrowness of Behring's Straits precludes the supposition that the tides in the Arctic Ocean and among the channels of the Arctic Archipelago are sensibly influenced by communication through it with the Pacific.

The largeness of the values for the retardation of spring-tides renders it probable that for those places the tidal influence is derived chiefly from the Atlantic Ocean, and not by direct action of Sun and Moon on the waters of the Arctic Ocean.

The shortness of the series of these observations, especially those for Beechey Island, has rendered some departure from the usual mode of reduction desirable The following explanation is therefore necessary:—The observations were first grouped according to mean solar hours, and the summations and means obtained and the means analyzed The values of the mean solar amplitudes thus obtained were then used for the calculation of the height of the tide at each integral mean solar hour due to these constituents. The heights were then copied for the previous values grouped according to mean solar hours, subtracting from each quantity the effect of the height due to the mean sun, computed as above explained. These numbers were grouped according to mean lunar hours, and the series of mean values analyzed as before. The value of the tide at each mean lunar hour was then computed and subtracted from the previously copied series, and grouped according to sidereal hours and the reduction continued as before; and so on throughout the seven evaluated series. The values obtained for the smaller components found by these means are no doubt trustworthy.

Notes on the Reductions of the Tidal Observations of Brest and Toulon.

By Mr. Roberts.

"With the kind assistance of M. Janssen the tracings from the original "registered tidal observations at Toulon for the whole of the year 1853 were "obtained from the Department of the Marine at Paris, and also a copy of "the heights at Brest for the year 1875. These two years' observations have "been treated and reduced in a similar manner to the many years' tidal obser-"vations fully described in the Reports of the Tidal Committee of the British "Association for the years 1868 to 1872. It will therefore be only necessary "in this place to give a general summary of the results obtained. The ob-"servations being given in metres, the results have been similarly expressed "in decimetres and centimetres, and not in English feet.

"*Brest.*

"The proportion between the solar and lunar semidiurnal tides at Brest is "(allowing for the value of the Moon's declination) about as 1 to 3, and “agrees fairly with the proportion found at most British ports. The elliptic semidiurnal tides agree within narrow limits with the values assigned by theory, as also those of the *Evection* and *Variation* semidiurnal. The overtides here, as at Toulon, are small, the mean lunar quarter-diurnal components amounting to 4·8 centimetres only, the main lunar semidiurnal tide being 1·9887 metre. The terdiurnal component is about $\frac{1}{100}$ of the chief tide, which accords with the proportion found at British ports. The diurnal components at Brest are very small, and are only about double the amounts found for Toulon, although the range of tide is about thirty times greater.

Toulon.

“The proportion between the solar and lunar semidiurnal tides at Toulon, having regard to the fact that the inclination of the Moon's maximum orbit to the earth's equator for the year reduced was nearly at its greatest, agrees very nearly with that assigned to it by the Equilibrium theory, and was found to be about as 1 to 2·2. The overtides of the main semidiurnal components were found to be very small, the largest that of the first overtide of the lunar semidiurnal, scarcely exceeding 3 millimetres. The terdiurnal lunar tide amounts to about $\frac{1}{47}$ of the main lunar semidiurnal, the proportion generally found for this component from many years reductions at different ports being about $\frac{1}{50}$ of the chief component. The proportion between the longer elliptic and the lunar semidiurnal is somewhat larger than the deduced value according to the equilibrium theory, although that between the larger and smaller components agrees almost exactly. The semidiurnal tides depending on the lunar perturbations of *Evection* and *Variation* agree within reasonable limits with the equilibrium theoretical proportions. The evaluated diurnal components are very large, the luni-solar exceeding in value the mean solar semidiurnal. These large diurnal components give to the Mediterranean tides a totally different character from those of the North Atlantic, in which the diurnal tides are very small. The coincidence of phase of the main lunar and solar semidiurnal tides happening some 4 or 5 hours *before* the time of New or Full Moon would point to the conclusion that the tides at Toulon were wholly generated in the Mediterranean, and were scarcely if at all influenced by any action of the North Atlantic through the Straits of Gibraltar, the amount of retardation of coincidence of phase for these components amounting on the western coast of Europe to between 30 and 40 hours. The evaluation of the long-period tides places the maximum of the solar annual tide at Dec. 30. The value of the lunar declinational fortnightly tide is about 1½ centimetres, or $\frac{6}{10}$ inch.”

Brest (Lat 48° 23′ 24″ N, Long 4° 29′ 33″ W of Greenwich) Year 1875

	S	M	K	O	P	L	N	λ	ν	μ
R_1	0·046	0·021	0·703	0·760	0·217					
ϵ_1	51°·74	221°·59	158°·09	229°·72	329°·48					
R_2	7·776	19·887	2·208			0·636	4·043	0·174	0·863	0·868
ϵ_2	13[illegible]°·92	100°·27	147°·16			299°·55	83°·25	239°·28	44°·98	93°·23
R_3		0·191								
ϵ_3		3°·02								
R_4		0·478								
ϵ_4		86°·11								
R_6		0·289								
ϵ_6		326°·55								
R_8		0·020								
ϵ_8		205°·12								

The amplitudes are expressed in decimetres

Toulon (Lat 43° 7′ 20″ N Long 5° 55′ 31″ E of Greenwich) Year 1853

	S	M	K	O	P	J	Q	L	N	λ	ν	μ
R_1	0·295	0·466	3·668	1·876	1·255	0·250	0·192					
ϵ_1	185°·63	198°·35	101°·42	201°·66	269°·94	116°·78	141 97					
R_2	2·742	5·752	0·805					0·210	1·387	0·100	0·256	0·215
ϵ_2	249°·77	254°·56	271°·46					60°·99	241°·81	192°·45	221°·37	222°·96
R_3		0·134										
ϵ_3		[illegible]°·27										
R_4	0·060	0·326										
ϵ_4	297°·72	353°·43										
R_6		0·049										
ϵ_6		157°·92										
R_8		0·040										
ϵ_8		154°·28										

The amplitudes are expressed in centimetres

	Brest		Toulon	
	R	ε	R	ε
Lunar monthly tide	1·01	327°·51	1·79	228°·05
Lunar fortnightly tide	3·02	80·65	1·55	139·50
Lunisolar fortnightly tide	8·53	51·15	0·55	50·61
Solar annual tide	7·94	233·76	4·79	278·87
Solar semiannual tide	2·17	92·74	2·74	143·80

The amplitudes are expressed in centimetres

	Brest	Toulon	
	days.	days	
Coincidence of phase of S and M	1·544	−0·196	After New and Full Moon
Coincidence of phase of P and O	4·092	2·802	
Coincidence of phase of M and N	1·303	0·976	After Moon's Perigees.
Opposition of phase of L and M	−1·475	1·038	

Definition of ϵ.

To explain the meaning of the values of ϵ given in the preceding Tables of results it is convenient to use Laplace's "astres fictifs," or ideal stars. Let them be as follows:—

M	the "mean Moon."		
S	the "mean Sun."		
K	the "first point of Aries" or ♈		
O	a point moving with angular velocity	2σ,	and coinciding with M when M is in ♈
Q	" " "	$3\sigma-\varpi$,	" " M when the longitude of M is half the longitude of the perigee.
P	" " "	2η,	" " S when S is in ♈.
J	" " "	$-\sigma+\varpi$,	or *diminishing* in right ascension at the rate $\sigma-\varpi$, and passing through ♈ when M is in perigee.
N	" " "	$\frac{3}{2}\sigma-\frac{1}{2}\varpi$,	and passing alternately through the perigee and apogee of the moon's orbit when M is in perigee.
L	" " "	$\frac{1}{2}\sigma+\frac{1}{2}\varpi$,	" " " " " "
ν	" " "	$\frac{3}{2}\sigma-\eta+\frac{1}{2}\varpi$,	and coinciding with M when the longitude of S is equal to the mean of the longitudes of M and [of the perigee of the Moon's orbit.
λ	" " "	$\frac{1}{2}\sigma+\eta-\frac{1}{2}\varpi$,	" " " " " "
μ	" " "	$2\sigma-\eta$,	and coinciding with M when the longitudes of M and S are equal

The value of ϵ in each case above means the number of $\frac{1}{360}$ part of its period which the corresponding tidal constituent has still to execute till its high water from the instant when the ideal star crosses the meridian of Greenwich if the place is in England, or the meridian of the place if not in England. Thus if n denote the periodic speed of the particular tide in mean solar hours, its time of high water is $\frac{\epsilon}{n}$, reckoned in mean solar hours after the transit of the ideal star.

The notation relatively to n and ϵ is somewhat different in what follows, as the reader will see; but no confusion can arise in consequence.

To facilitate comparisons between the various results of the harmonic analysis contained in this and the preceding Reports and to promote a complete theoretical appreciation of them all the following harmonic analysis of the equilibrium tide will be found useful A portion of it that namely, pertaining to the mean semidiurnal the declinational semidiurnal and the elliptic semidiurnal constituents was given in the Report for 1872 (§§ 48, 50) For the sake of clearness an investigation of the equilibrium tide, consisting chiefly of extracts from Thomson and Tait's 'Natural Philosophy' vol i is premised as the first edition of that work is out of print and the second edition can scarcely appear until after the publication of this Report

Let E denote the earth's mass M the mass of the moon or sun D the distance between the centres of the two bodies a the earth's radius If we neglect tides depending on the fourth and higher powers of $\frac{a}{D}$ (of which only one, Laplace's terdiurnal lunar tide referred to in § 3 of the Committee's Report for 1868 and again in § 5 1872 can probably be sensible) the equilibrium tide will not be altered by the following arbitrary but conveniently symmetrical assumption Imagine M to be divided into two halves and let these be fixed at distances each equal to D on opposite sides of the earth in a line through its centre Then if r θ be polar coordinates of any point referred to the earth's centre as origin and the line joining the two disturbing bodies as axis the equation of an equipotential surface is [Thomson and Tait, §§ 804 811]

' $$\frac{E}{r}+\tfrac{1}{2}M\left[\frac{1}{\sqrt{(D^2-2rD\cos\theta+r^2)}}+\frac{1}{\sqrt{(D^2+2rD\cos\theta+r^2)}}\right]=\text{const} \qquad (11),$$

and as the first approximation for $\frac{r}{D}$ is very small, we have

$$\frac{E}{r}+\frac{M}{D}\left[1+\tfrac{1}{2}\frac{r^2}{D^2}(3\cos^2\theta-1)\right]=\text{const} \qquad (12)$$

whence finally if $r=a+u$ u being infinitely small

$$u=\tfrac{1}{2}\frac{Ma^4}{ED^3}(3\cos^2\theta-1) \qquad (13).$$

This is a spherical surface harmonic of the second order and $\frac{Ma^3}{ED^3}$ is one quarter of the ratio that the difference between the moon's attraction on the nearest and furthest parts of the earth bears to terrestrial gravity Hence

' The fluid will be disturbed into a prolate ellipsoidal figure with its long axis in the line joining the two disturbing bodies and with ellipticity equal to $\frac{3}{4}$ of the ratio which the difference of attractions of one of the disturbing bodies on the nearest and furthest points of the fluid surface bears to the surface value of the attraction of the nucleus If, for instance, we suppose the moon to be divided into two halves and these to be fixed on opposite sides of the earth at distances each equal to the true moon's mean distance, the ellipticity of the disturbed terrestrial level would be $\frac{3}{2\times 60\times 300000}$, or $\frac{1}{12{,}000{,}000}$, and the whole difference of levels from highest to lowest would be about $1\frac{3}{4}$ feet We shall have much occasion to use this hypothesis in vol. ii in investigating the kinetic theory of the tides

"805. The rise and fall of water at any point of the earth's surface we may now imagine to be produced by making these two disturbing bodies (moon and anti-moon, as we may call them for brevity) revolve round the earth's axis once in the lunar twenty-four hours, with the line joining them always inclined to the earth's equator at an angle equal to the moon's declination. If we assume that at each moment the condition of hydrostatic equilibrium is fulfilled, that is, that the free liquid surface is perpendicular to the resultant force, we have what is called the 'equilibrium theory of the tides.'

"806. But even on this equilibrium theory, the rise and fall at any place would be most falsely estimated if we were to take it, as we believe it is generally taken, as the rise and fall of the spheroidal surface that would bound the water were there no dry land (uncovered solid). To illustrate this statement, let us imagine the ocean to consist of two circular lakes A and B, with their centres 90° asunder, on the equator, communicating with one another by a narrow channel. In the course of the lunar twelve hours the level of lake A would rise and fall, and that of lake B would simultaneously fall and rise to maximum deviations from the mean level. If the areas of the two lakes were equal, their tides would be equal, and would amount in each to about ⅞ of a foot above and below the mean level, but not so if the areas were unequal. Thus, if the diameter of the greater be but a small part of the earth's quadrant, not more, let us say, than 20°, the amounts of the rise and fall in the two lakes will be inversely as their areas to a close degree of approximation. For instance, if the diameter of B be only ⅒ of the diameter of A, the rise and fall in A will be scarcely sensible, while the level of B will rise and fall by about 1¾ feet above and below its mean; just as the rise and fall of level in the open cistern of an ordinary barometer is but small in comparison with fall and rise in the tube. Or, if there be two large lakes, A, A′, at opposite extremities of an equatorial diameter, two small ones, B, B′, at two ends of the equatorial diameter perpendicular to that one, and two small lakes, C, C′, at two ends of the polar axis, the largest of these being, however, still supposed to extend over only a small portion of the earth's curvature, and all the six lakes communicate with one another freely by canals or underground tunnels: there will be no sensible tides in the lakes A and A′; in B and B′ there will be high water of 1¾ feet above mean level when the moon or anti-moon is in the zenith, and low water of 1¾ feet below mean when the moon is rising or setting; and at C and C′ there will be tides rising and falling ⅞ of a foot above and below the mean, the time of low water being when the moon or anti-moon is in the meridian of A, and of high water when they are on the horizon of A. The simplest way of viewing the case for the extreme circumstances we have now supposed is, first, to consider the spheroidal surface that would bound the water at any moment if there were no dry land, and then to imagine this whole surface lowered or elevated all round by the amount required to keep the height at A and A′ invariable. Or, if there be a large lake A in any part of the earth, communicating by canals with small lakes over various parts of the surface, having in all but a small area of water in comparison with that of A, the tides in any of these will be found by drawing a spheroidal surface of 1¾ feet difference between greatest and least radius, and, without disturbing its centre, adding or subtracting from each radius such a length, the same for all, as shall do away with rise or fall at A.

"807. It is, however, only on the extreme supposition we have made, of one water area much larger than all the others taken together, but yet itself covering only a small part of the earth's curvature, that the rise and fall can be done away with nearly altogether in one place, and doubled in another place Taking the actual figure of the earth's sea surface we must subtract a certain positive or negative quantity a from the radius of the spheroid that would bound the water were there no land a being determined according to the moon's position to fulfil the condition that the volume of the water remains unchanged and being the same for all points of the sea at the same time Many writers on the tides have overlooked this obvious and essential principle indeed we know of only one sentence* hitherto published in which any consciousness of it has been indicated

The quantity α is a spherical harmonic function of the second order of the moon's declination and hour angle from the meridian of Greenwich of which the five constant coefficients depend merely on the configuration of land and water and may be easily estimated approximately by not very laborious quadratures with data derived from the inspection of good maps

808 Let as above

$$r=a(1+u) \tag{14}$$

be the spheroidal level that would bound the water were the whole solid covered u being given by (13) of § 804 Thus if $\iint d\sigma$ denote surface integration over the whole surface of the sea

$$a\iint u\,d\sigma$$

expresses the addition (positive or negative as the case may be) to the volume required to let the water stand to this level everywhere To do away with this change of volume we must suppose the whole surface lowered equally all over by such an amount α (positive or negative) as shall equalize it Hence if Ω be the whole area of sea we have

$$\alpha=\frac{a\iint u\,d\sigma}{\Omega} \tag{15}$$

And

$$\mathfrak{r}=r-\alpha=a\left\{1+u-\frac{\iint u\,d\sigma}{\Omega}\right\} \tag{16}$$

is the corrected equation of the level spheroidal surface of the sea Hence

$$h=a\left\{u-\frac{\iint u\,d\sigma}{\Omega}\right\} \tag{17}$$

where h denotes the height of the surface of the sea at any place above the level which it would take if the moon were removed

To work out (15) put first for brevity

$$\tau=\tfrac{3}{2}\frac{Ma^3}{ED^3} \tag{18}$$

and (13) becomes

$$u=\tau(\cos^2\theta-\tfrac{1}{3}) \tag{19}$$

Now let l and λ be the geographical latitude and west longitude of the place to which u corresponds and ψ and δ the moon's hour angle from the meridian of Greenwich and her declination As θ is the moon's zenith distance at the place (corrected for parallax) we have by spherical trigonometry

$$\cos\theta=\cos l\cos\delta\cos(\lambda-\psi)+\sin l\sin\delta,$$

which gives

$$3\cos^2\theta-1=$$
$$\tfrac{3}{2}\cos^2 l\cos^2\delta\cos 2(\lambda-\psi)+6\sin l\cos l\sin\delta\cos\delta\cos(\lambda-\psi)+\tfrac{1}{2}(3\sin^2\delta-1)(3\sin^2 l-1) \tag{20}$$

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* "Rigidity of the Earth" § 17 Phil Trans 1862

Hence if we take $\mathfrak{A}$, $\mathfrak{B}$, $\mathfrak{C}$, $\mathfrak{D}$, $\mathfrak{E}$ to denote five integrals depending solely on the distribution of land and water, expressed as follows —

$$\left.\begin{array}{ll} \mathfrak{A}=\dfrac{1}{\Omega}\iint\cos^2 l\cos 2\lambda d\sigma, & \mathfrak{B}=\dfrac{1}{\Omega}\iint\cos^2 l\sin 2\lambda d\sigma, \\ \mathfrak{C}=\dfrac{1}{\Omega}\iint\sin l\cos l\cos\lambda d\sigma, & \mathfrak{D}=\dfrac{1}{\Omega}\iint\sin l\cos l\sin\lambda d\sigma, \\ \mathfrak{E}=\dfrac{1}{\Omega}\iint(3\sin^2 l-1)d\sigma, & \end{array}\right\} \quad . \quad . \quad (21).$$

where of course $d\sigma=\cos l dl d\lambda$,

we have

$$a=\frac{a}{\Omega}\iint u d\sigma=$$
$$\tfrac{1}{3}a\tau\{\tfrac{3}{2}\cos^2\delta(\mathfrak{A}\cos 2\psi+\mathfrak{B}\sin 2\psi)+6\sin\delta\cos\delta(\mathfrak{C}\cos\psi+\mathfrak{D}\sin\psi)+\tfrac{1}{2}\mathfrak{E}(3\sin^2\delta-1)\}(22).$$

This, used with (19) and (20) in (17), gives for the full conclusion of the equilibrium theory,

$$\left.\begin{array}{l} h= \\ \tfrac{1}{6}a\tau(3\sin^2 l-1-\mathfrak{E})(3\sin^2\delta-1) \\ +2a\tau[(\sin l\cos l\cos\lambda-\mathfrak{C})\cos\psi+(\sin l\cos l\sin\lambda-\mathfrak{D})\sin\psi]\sin\delta\cos\delta \\ +\dfrac{a\tau}{2}[(\cos^2 l\cos 2\lambda-\mathfrak{A})\cos 2\psi+(\cos^2 l\sin 2\lambda-\mathfrak{B})\sin 2\psi]\cos^2\delta \end{array}\right\} \quad . \quad (23),$$

in which the value of τ may be taken from (18) for either the moon or the sun; and δ and ψ denote the declination and Greenwich hour-angle of one body or the other, as the case may be. In this expression we may of course reduce the semidiurnal terms to the form A $\cos(2\psi-\epsilon)$, and the diurnal terms to A′ $\cos(\psi-\epsilon')$. Interpreting it we have the following conclusions:—

"809. In the equilibrium theory, the whole deviation of level at any point of the sea, due to sun and moon acting jointly, is expressed by the sum of six terms, three for each body.

"(1) The lunar or solar semidiurnal tide rises and falls in proportion to a simple harmonic function of the hour-angle from the meridian of Greenwich, having for period 180° of this angle (or in time, half the period of revolution relatively to the earth), with amplitude varying in simple proportion to the square of the cosine of the declination of the sun or moon, as the case may be, and therefore varying but slowly, and through but a small entire range.

"(2) The lunar or solar diurnal tide varies as a simple harmonic function of the hour-angle of period 360°, or twenty-four hours, with an amplitude varying always in simple proportion to the sine of twice the declination of the disturbing body, and therefore changing from positive maximum to negative, and back to positive maximum again, in the tropical* period of either body in its orbit.

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* The tropical period differs from the sidereal period in being reckoned from the first point of Aries instead of from a line fixed in space, the difference for the case of the sun being only one in 26,000 years, and for the case of the moon one in 13×18·6

"(3) The lunar fortnightly or solar semiannual tide is a variation on the average height of water for the twenty-four lunar or the twenty-four solar hours, according to which there is on the whole higher water all round the equator and lower water at the poles, when the declination of the disturbing body is zero, than when it has any other value, whether north or south, and maximum height of water at the poles and lowest at the equator, when the declination has a maximum, whether north or south Gauss's way of stating the circumstances on which 'secular' variations in the elements of the solar system depend is convenient for explaining this component of the tides Let the two parallel circles of the north and south declination of the moon and anti-moon at any time be drawn on a geocentric spherical surface of radius equal to the moon's distance and let the moon's mass be divided into two halves and distributed over them As these circles of matter gradually vary each fortnight from the equator to maximum declination and back, the tide produced will be solely and exactly the 'fortnightly tide'

'810 In the equilibrium theory as ordinarily stated, there is at any place high water of the semidiurnal tide *precisely* when the disturbing body, or its opposite, crosses the meridian of the place and its amount is the same for all places in the same latitude, being as the square of the cosine of the latitude, and therefore, for instance, zero at each pole In the corrected equilibrium theory, high water of the semidiurnal tides may be either before or after the disturbing body crosses the meridian, and its amount is very different at different places in the same latitude, and is certainly not zero at the poles In the ordinarily stated equilibrium theory, there is, *precisely* at the time of transit, high water or low water of diurnal tides in the northern hemisphere according as the declination of the body is north or south, and the amount of the rise and fall is in simple proportion to the sine of twice the latitude, and therefore vanishes both at the equator and at the poles In the corrected equilibrium theory, the time of high water may be considerably either before or after the time of transit and its amount is very different for different places in the same latitude, and certainly not zero at either equator or poles In the ordinary statement there is no lunar fortnightly or semiannual tide in the latitude 35° 16 (being $\sin^{-1}\frac{1}{\sqrt{3}}$), and its amount in other latitudes is in proportion to the deviations of the squares of their sines from the value ⅓ In the corrected equilibrium theory each of these tides is still the same in the same latitude, and vanishes in a certain latitude, and in any other latitudes is in simple proportion to the deviation of the squares of their sines from the square of the sine of that latitude But the latitude where there is no tide of this class is not $\sin^{-1}\frac{1}{\sqrt{3}}$ but $\sin^{-1}\left(\sqrt{\frac{1+\mathfrak{E}}{3}}\right)$, where $\mathfrak{E}$ is the mean value of $3\sin^2 l-1$ for the whole covered portion of the earth's surface, a quantity easily estimated by a not very laborious quadrature, from sufficiently complete geographical data of the coast lines for the whole earth.

"As the fortnightly and semiannual tides most probably follow in reality very nearly the equilibrium law, it becomes a matter of great importance to evaluate this quantity, but we regret that hitherto we have not been able to undertake the work Conversely, it is possible that careful determination of the fortnightly tides at various places, by proper reduction of tidal observations, may contribute to geographical knowledge as to the amount of water surface in the hitherto unexplored districts of the arctic and antarctic regions

"811 The superposition of the solar semidiurnal on the lunar semidiurnal tide has been investigated above (§ 60) as an example of the composition of simple harmonic motions and the well known phenomena of the spring tides and neap tides and of the priming and lagging have been explained We have now only to add that observation proves for almost all places whether oceanic islands or other open coast stations or in deep bays estuaries or tidal rivers the proportionate difference between the heights of spring tides and neap tides and the amount of the priming and lagging to be much less than estimated in § 60 on the equilibrium hypothesis and to be very different in different places as we shall see in vol ii is to be expected from the kinetic theory

The four lunar and solar diurnal and semidiurnal tides spoken of in § 809 of the preceding extract are in the harmonic analysis of this Committee resolved into harmonic constituents with constant amplitudes and epochs instead of the varying amplitudes and epochs which that statement implies in virtue of the varying distances of the sun and moon from the earth and of the differences of their right ascensions from those of ideal bodies moving uniformly in the plane of the earth's equator with constant angular velocities equal to the mean angular velocities of the sun and moon round the earth

To investigate for either moon or sun alone the equilibrium values of these simple harmonic constituents and to exhibit the simple harmonic expression for the long period declinational tide represented by the first line of (238) § 80 call L the value of this line D the value of the second line (or the whole complex diurnal equilibrium tide) and S the value of the third line (or semidiurnal equilibrium tide)

Put

$$3\sin^2 l - 1 - \mathfrak{E} = K$$

$$\sin l \cos l \cos \lambda - \mathfrak{C} = F \cos f \qquad \sin l \cos l \sin \lambda - \mathfrak{D} = F \sin f$$

$$\cos^2 l \cos 2\lambda - \mathfrak{A} = G \cos 2g \qquad \cos^2 l \sin 2\lambda - \mathfrak{B} = G \sin 2g$$

Then

$$L = \frac{1}{6} a\tau K(3\sin^2\delta - 1) \tag{I}$$

$$D = 2a\tau \sin\delta \cos\delta \quad F\cos(\psi - f) \tag{II}$$

$$S = \frac{a\tau}{2}\cos^2\delta \quad G\cos 2(\psi - g) \tag{III}$$

where F f G g are constants for each place having different values for different places Let ϕ be the angle between the body's radius vector and the ascending node of its orbit relatively to the earth's equator (which for the case of the sun will be his longitude) let ν be the right ascension of this node (which for the case of the sun is of course zero) let α denote the right ascension of the body reckoned from this node (which for the sun will be his right ascension measured from the first point of Aries) let I denote the inclination of the body's orbit to the plane of the earth's equator (which for the case of the sun is nearly enough constant for our purposes and equal to 23° 27 19) lastly let χ denote the sidereal time reduced to angle, that is to say, the Greenwich hour angle of the first point of Aries We have

$$\psi = \chi - \alpha - \nu$$

Hence by (I.) and (II),

$$D=2\alpha\tau F\{\cos(\chi-\nu-f)\cos\alpha+\sin(\chi-\nu-f)\sin\alpha\}\sin\delta\cos\delta, \quad . \quad . \quad (IV)$$

$$S=\frac{\alpha\tau}{2}G\{\cos 2(\chi-\nu-g)\cos 2\alpha+\sin 2(\chi-\nu-g)\sin 2\alpha\}\cos^2\delta. \quad . \quad . \quad . \quad (V.)$$

Now δ and α are the two legs of a right-angled triangle of which ϕ is the hypotenuse and I the angle opposite to δ. Hence, by spherical trigonometry,

$$\sin\delta=\sin I\sin\phi,$$
$$\cos\alpha\cos\delta=\cos\phi,$$
$$\sin\alpha\cos\delta=\sin\phi\cos I.$$

Hence $$\sin^2\delta=\tfrac{1}{2}\sin^2 I(1-\cos 2\phi),$$

and so $$L=\tfrac{1}{4}\alpha\tau K(-\tfrac{2}{3}+\sin^2 I-\sin^2 I\cos 2\phi). \quad . \quad . \quad . \quad . \quad . \quad (VI)$$

Next for the diurnal tide

$$\sin\delta\cos\delta\cos\alpha=\sin I\sin\phi\cos\phi=\tfrac{1}{2}\sin I\sin 2\phi,$$

and $$\sin\delta\cos\delta\sin\alpha=\sin I\sin^2\phi\cos I=\tfrac{1}{2}\sin I(1-\cos 2\phi)\cos I,$$

and using these in (IV) we find (VII), page 301.

Similarly, towards reducing for the semidiurnal,

$$\cos 2\alpha\cos^2\delta=(2\cos^2\alpha-1)\cos^2\delta=2\cos^2\phi-(1-\sin^2 I\sin^2\phi)$$
$$=\cos 2\phi(1-\tfrac{1}{2}\sin^2 I)+\tfrac{1}{2}\sin^2 I=\cos 2\phi(\tfrac{1}{2}+\tfrac{1}{2}\cos^2 I)+\tfrac{1}{2}\sin^2 I,$$

and $$\sin 2\alpha\cos^2\delta=2\sin\alpha\cos\delta\cos\alpha\cos\delta=\cos I\sin 2\phi.$$

Using these in (V) we find (VIII), page 301.

The sum of these three expressions (VI), (VII), and (VIII.),

$$h=L+D+S, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (IX.)$$

would be the required complete simple harmonic expansion, if τ were constant, and if ϕ increased simply in proportion to the time

To complete the process we must, by aid of physical astronomy, express τ and ϕ in terms of χ.

For the case of the sun, the only deviation from uniform circular motion which produces sensible influence on the tides is the elliptic inequality, for the case of the moon we must take into account also the perturbations called evection and variation.

For the case of the sun we have

$$\tau=\tfrac{3}{2}\frac{S}{E}p^3,\ I=\omega;\ \nu=0; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (X.)$$

if E denote the earth's mass, S the sun's mass, p his parallax at any time, and ω the obliquity of the ecliptic. Let P denote the mean parallax, ϖ the longitude of the perihelion, and e the eccentricity of the orbit. As ϕ now denotes the sun's longitude, we have by the polar equation of the ellipse with one focus as pole,

$$p=P\{1+e\cos(\phi-\varpi)\};$$

and by Kepler's first law $\frac{1}{p^2}\frac{d\phi}{d\chi}$ is constant.

$$\begin{aligned}D&=a r \sin I \,.\, F\{\sin 2\phi \cos(\chi-\nu-f)-\cos 2\phi \sin(\chi-\nu-f)\cos I+\sin(\chi-\nu-f)\cos I\}\\ &=a r \sin I \,.\, F\{-\sin(\chi-2\phi-\nu-f)\cos^2\tfrac{1}{2}I+\sin(\chi+2\phi-\nu-f)\sin^2\tfrac{1}{2}I+\cos I \,.\, \sin(\chi-\nu-f)\} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad \text{(VII.)}\end{aligned}$$

$$S=\frac{ar}{2}G\left\{\left(\frac{1+\cos I}{2}\right)^2\cos 2(\chi-\phi-\nu-g)+\left(\frac{1-\cos I}{2}\right)^2\cos 2(\chi-\phi-\nu-g)+\tfrac{1}{3}\sin^2 I\cos 2(\chi-\nu-g)\right\} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad \text{(VIII.)}$$

$$\begin{aligned}p^3\sin(-2\phi+A)&=P^3\left\{\sin\left(-\frac{2\eta}{\gamma}\chi-2\odot+A\right)-4e\cos\left(-\frac{2\eta}{\gamma}\chi-2\odot+A\right)\sin\left(\frac{\eta}{\gamma}\chi+\odot-\varpi\right)+3e\sin\left(-\frac{2\eta}{\gamma}\chi-2\bigcirc+A\right)\cos\left(\frac{\eta}{\gamma}\chi+\odot-\varpi\right)\right\}\\ &=P^3\left[\sin\left(-\frac{2\eta}{\gamma}\chi-2\odot+A\right)+\tfrac{7}{2}e\sin\left(-\frac{3\eta}{\gamma}\chi-3\odot+A+\varpi\right)-\tfrac{1}{2}e\sin\left(-\frac{\eta}{\gamma}\chi-\odot+A-\varpi\right)\right] \quad . \; . \; . \quad \text{(XII.)}\end{aligned}$$

$$\begin{aligned}h=\tfrac{3}{2}\frac{S}{E}P^3a\Bigg[&\tfrac{1}{4}K\left\{-\tfrac{2}{3}+\sin^2\omega-2e\cos\left(\frac{\eta}{\gamma}\chi+\odot-\varpi\right)-\sin^2\omega\cos 2\left(\frac{}{\gamma}\chi+\odot\right)\right\}\\ &+F\sin\omega\left\{\cos^2\tfrac{1}{2}\omega\left[-\sin\left(\left(1-2\frac{\eta}{\gamma}\right)\chi-2\odot-f\right)-\tfrac{7}{2}e\sin\left(\left(1-\frac{3\eta}{\gamma}\right)\chi-3\bigcirc-f+\varpi\right)+\tfrac{1}{2}e\sin\left(\left(1-\frac{\eta}{\gamma}\right)\chi-\bigcirc-f-\varpi\right)\right]\right.\\ &+\sin^2\tfrac{1}{2}\omega\sin\left(\left(1+2\frac{\eta}{\gamma}\right)\chi+2\odot-f\right)+\cos\omega\left.\left[\sin(\chi-f)+\tfrac{3}{2}e\sin\left(\left(1+\frac{\eta}{\gamma}\right)\chi+\bigcirc-f-\varpi\right)+\tfrac{3}{2}e\sin\left(\left(1-\frac{\eta}{\gamma}\right)\chi-\odot-f+\varpi\right)\right]\right\}\\ &+\tfrac{1}{2}G\left\{\left(\frac{1+\cos\omega}{2}\right)^2\left[\cos 2\left(\left(1-\frac{\eta}{\gamma}\right)\chi-\odot-g\right)+\tfrac{7}{2}e\cos\left(\left(2-3\frac{\eta}{\gamma}\right)\chi-3\odot-2g+\varpi\right)-\tfrac{1}{2}e\cos\left(\left(2-\frac{\eta}{\gamma}\right)\chi-\odot-2g-\varpi\right)\right]\right.\\ &\left.+\left(\frac{1-\cos\omega}{2}\right)^2\cos 2\left(\left(1-\frac{\eta}{\gamma}\right)\chi-\odot-g\right)+\tfrac{1}{2}\sin^2\omega\cos 2(\chi-g)\right\}\Bigg] \,. \qquad \text{(XIII.)}\end{aligned}$$

$$\begin{aligned}\tfrac{3}{2}\frac{M}{E}P'^3\left(\frac{1+\cos I}{2}\right)^2 G\frac{\eta}{c}\Bigg\{&\frac{\gamma\times 15e'}{16}\cos\left[\left(2-\frac{3\sigma}{\gamma}+\frac{2\eta}{\gamma}\right)\chi-3\rightmoon+2\odot-\varpi'-2g\right]-\frac{15e'}{16}\cos\left[\left(2-\frac{\sigma}{\gamma}-\frac{2\eta}{\gamma}\right)\chi'-\rightmoon-2\bigcirc+\varpi'-2g\right]\\ &+\frac{13}{16}\frac{\eta}{\sigma}\cos\left[2\left(1-\frac{\eta}{\gamma}\right)\chi-2(\odot+g)\right]+\frac{85}{16}\frac{\eta}{\sigma}\cos\left[2\left(1+\frac{\eta}{\gamma}-\frac{2\sigma}{\gamma}\right)\chi-2(2\rightmoon-\odot+g)\right]\Bigg\} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad \text{(XIV.)}\end{aligned}$$

Hence if η denote the mean angular velocity of the sun's radius vector, γ the angular velocity of the earth's rotation, and $\odot$ the mean sun's right ascension (or, which is the same, the sun's "mean longitude") at the instant of the first transit of ♈ after the vernal equinox of the year, we have

$$\frac{d\phi}{d\chi}=\frac{\eta}{\gamma}\{1+e\cos(\phi-\varpi)\}^2$$

$$=\frac{\eta}{\gamma}\{1+2e\cos(\phi-\varpi)\}\text{ approximately}$$

$$=\frac{\eta}{\gamma}\left\{1+2e\cos\left(\frac{\eta}{\gamma}\chi+\odot-\varpi\right)\right\}\text{ approximately.}$$

Henceforward χ must denote the whole angle turned through by the earth from the instant of the first transit of ♈ across the meridian of Greenwich after a time when the sun's longitude was zero.

Hence, integrating,

$$\phi=\odot+\frac{\eta}{\gamma}\chi+2e\sin\left(\frac{\eta}{\gamma}\chi+\odot-\varpi\right).$$

Now, if A denote any angle,

$$\sin(-2\phi+A)=$$

$$\sin\left(-2\odot-\frac{2\eta}{\gamma}\chi+A\right)-4e\cos\left(-2\odot-\frac{2\eta}{\gamma}\chi+A\right)\sin\left(\frac{\eta}{\gamma}\chi+\odot-\varpi\right)\text{ approximately:}$$

and therefore as

$$p^3=P^3\left[1+3e\cos\left(\frac{\eta}{\gamma}\chi-\varpi\right)\right]\text{ approximately. . . . (XI.)}$$

we have (XII.) (see page 301).

Going back now to (VI.), (VII.), and (VIII.), and attending to (X.), use (XI.) in the first term of (VI.) and the last term of (VII.), neglect the variation of parallax and put $\phi=\frac{\eta}{\gamma}\chi+\odot$ in the small terms of (VI.), (VII.), and (VIII.), use (XII.) in the first terms of (VII.) and (VIII.), giving to A the respective values $\chi-f$ and $\frac{\pi}{2}+2(\chi-g)$; and collect as in (IX.). we find (XIII.), (page 301).

To obtain the corresponding expression for the moon's equilibrium tide, substitute in the preceding, h' for h, M for S, P′ for P, I for ω, e' for e, σ for η, ☽ $-\nu$ for $\odot$, $\varpi'-\nu$ for ϖ, $f+\nu$ for f, and $g+\nu$ for g: M denoting the moon's mass, ν the right ascension of the ascending node of the moon's orbit on the earth's equator, ☽ the mean moon's right ascension at the time of that transit of ♈ across the meridian of Greenwich from which χ (as stated above) is reckoned, ϖ' the longitude of the moon's perigee, σ the mean angular velocity of the moon's radius vector, and e' the eccentricity of her orbit. With these explanations, it is better not to write out the formula, but rather to refer to (XIII.). But to complete the harmonic expression of the lunar equilibrium tide, so far as practically useful, we must include terms resulting from evection and variation, Mr Roberts having, in working out the harmonic analysis of the Liverpool tides for the Committee, discovered very sensible effects of these perturbations of the moon's motion, and having thenceforward analyzed for them regularly in every case in which the data were sufficiently complete. The only term of (VI.), (VII.), or (VIII.) having evectional and variational constituents which can be sensible in North-Atlantic ports is the chief semidiurnal tide represented by the first term of (VIII.). For other seas than the North Atlantic, the evectional and variational constituents of the two chief lunar diurnal tides represented by the first and last terms of (VII.) may be quite sensible, but it is not worth while at present to work out the equilibrium-values of these constituents; it is enough to give the equilibrium-values of the evectional and variational perturbations of the chief semidiurnal tide, as it is only for these effects of evection and variation that the reductions hitherto performed give the data for comparison with observation.

The theoretical expressions for the effects of evection and variation on the moon's coordinates are —

	Evection	Variation
On longitude .	$\frac{15}{4}\frac{\eta}{\sigma}e'\sin\left[2(\phi'+\nu-\phi)-(\phi'+\nu-\varpi')\right]$;	$\frac{11}{8}\left(\frac{\eta}{\sigma}\right)^2\sin 2(\phi'+\nu-\phi)$.
On parallax .	$P\frac{15}{8}\frac{\eta}{\sigma}e'\cos\left[2(\phi'+\nu-\phi)-(\phi'+\nu-\varpi')\right]$,	$P\left(\frac{\eta}{\sigma}\right)^2\cos 2(\phi'+\nu-\phi)$.

In these expressions substitute for $\phi'+\nu$ and ϕ their approximate values,

$$\frac{\sigma}{\gamma}\chi+\text{☽} \quad \text{and} \quad \frac{\eta}{\gamma}\chi+\odot$$

use the results in the first term of (VIII.) modified to suit the moon; and work out according to (XI.) and (XII.). Thus we find, for the evectional and variational semidiurnal tides, the equation (XIV.), page 301.

In I. and II. of the following Tables, the coefficient (R), speed (n), and epoch (ϵ) of each of the simple harmonic terms of (XIII.) are given separately for convenience of reference. Table I. contains the values of these quantities for the case of the sun's equilibrium tide, Table II. those for the moon's equilibrium tide, with the addition of the evectional and variational constituents of the semidiurnal tides.

TABLE I

$T = \frac{3}{2}\frac{S}{E}P^3 a = 24.6746$ (a being taken in centimetres)

Distinguishing Letters	No. of Term	R ÷ T	n	e
	1	$-\frac{1}{4}K$	0	0
	2	$\frac{1}{4}K\sin^2\omega$	0	0
	3	$\frac{1}{2}Ke$	η	$180^\circ - \odot + \varpi$
	4	$\frac{1}{4}K\sin^2\omega$	2η	$180^\circ - 2\odot$
P	5	$F\sin\omega\cos^2\frac{1}{2}\omega$	$\gamma - 2\eta$	$f + 270^\circ + 2\odot$
	6	$\frac{7}{2}Fe\sin\omega\cos^2\frac{1}{2}\omega$	$\gamma - 3\eta$	$f + 270^\circ + 3\odot - \varpi$
	7	$\frac{1}{2}F\sin\omega\cos^2\frac{1}{2}\omega$	$\gamma - \eta$	$f + 90^\circ + \odot + \varpi$
	8	$F\sin\omega\sin^2\frac{1}{2}\omega$	$\gamma + 2\eta$	$f + 90^\circ - 2\odot$
K	9	$F\sin\omega\cos\omega$	γ	$f + 90^\circ$
	10	$\frac{3}{2}Fe\sin\omega\cos\omega$	$\gamma + \eta$	$f + 90^\circ - \odot + \varpi$
	11	$\frac{3}{2}Fe\sin\omega\cos\omega$	$\gamma - \eta$	$f + 90^\circ + \odot - \varpi$
S	12	$\frac{1}{2}G\left(\frac{1+\cos\omega}{2}\right)^2$	$2\gamma - 2\eta$	$2g + 2\odot$
T	13	$\frac{7}{4}Ge\left(\frac{1+\cos\omega}{2}\right)^2$	$2\gamma - 3\eta$	$2g + 3\odot - \varpi$
R	14	$\frac{1}{4}Ge\left(\frac{1+\cos\omega}{2}\right)^2$	$2\gamma - \eta$	$2g + 180^\circ + \odot + \varpi$
	15	$\frac{1}{2}G\left(\frac{1-\cos\omega}{2}\right)^2$	$2(\gamma + \eta)$	$2g - 2\odot$
K	16	$\frac{1}{4}G\sin^2\omega$	2γ	$2g$

TABLE II

$$\mathrm{T}=\frac{3}{2}\frac{\mathrm{M}}{\mathrm{E}}\mathrm{P}^3 a=53\,6045$$

Distinguishing Letter	No. of term	[illegible]	[illegible]	
	1	$\frac{1}{6}\mathrm{K}$	0	
	2	$\frac{1}{4}\mathrm{K}\sin \mathrm{I}$	0	
	3	$\frac{1}{2}\mathrm{K}e$	σ	180° − ☽ + ϖ
	4	$\frac{1}{4}\mathrm{K}\sin^2 \mathrm{I}$	2σ	180° 2☽ + 2ν
O	5	$\mathrm{F}\sin \mathrm{I}\cos \frac{1}{2}\mathrm{I}$	$\gamma-2\sigma$	f + 270° + 2☽ − ν
Q	6	$\frac{1}{2}\mathrm{F}e\sin \mathrm{I}\cos \frac{1}{2}\mathrm{I}$	$\gamma-3\sigma$	f + 270° + 3☽ − ν − ϖ
	7	$\frac{1}{2}\mathrm{F}e\sin \mathrm{I}\cos^2 \frac{1}{2}\mathrm{I}$	$\gamma-\sigma$	f + 90° + ☽ − ν + ϖ
	8	$\mathrm{F}\sin \mathrm{I}\sin^2 \frac{1}{2}\mathrm{I}$	$\gamma+2\sigma$	f + 90° − 2☽ + 2ν
K	9	$\mathrm{F}\sin \mathrm{I}\cos \mathrm{I}$	γ	f + 90° + ν
J	10	$\frac{3}{2}\mathrm{F}e\sin \mathrm{I}\cos \mathrm{I}$	$\gamma+\sigma$	f + 90° − ☽ + ν + ϖ
	11	$\frac{3}{2}\mathrm{F}e\sin \mathrm{I}\cos \mathrm{I}$	$\gamma-\sigma$	f + 90° + ☽ + ν − ϖ
M	12	$\frac{1}{2}\mathrm{G}\left(\frac{1+\cos \mathrm{I}}{2}\right)$	$2(\gamma-\sigma)$	2χ + 2☽
N	13	$\frac{7}{4}\mathrm{G}e\left(\frac{1+\cos \mathrm{I}}{2}\right)$	$2\gamma-3\sigma$	2χ + 3☽ − ϖ′
L	14	$\frac{1}{4}\mathrm{G}e\left(\frac{1+\cos \mathrm{I}}{2}\right)^2$	$2\gamma-\sigma$	2χ + 180° + ☽ + ϖ
	15	$\frac{1}{2}\mathrm{G}\left(\frac{1-\cos \mathrm{I}}{2}\right)$	$2(\gamma+\sigma)$	2χ − 2☽
K	16	$\frac{1}{4}\mathrm{G}\sin^2 \mathrm{I}$	2γ	2χ + 2ν
λ	17	$\frac{15}{32}\mathrm{G}e\left(\frac{1+\cos \mathrm{I}}{2}\right)^2\frac{\eta}{\sigma}$	$2\gamma-\sigma-2\eta$	2χ + 180° + ☽ + 2○ − ϖ
ν	18	$\frac{105}{32}\mathrm{G}e\left(\frac{1+\cos \mathrm{I}}{2}\right)^2\frac{\eta}{\sigma}$	$2\gamma-3\sigma+2\eta$	2χ + 3☽ − 2○ + ϖ
S	19	$\frac{1}{16}\mathrm{G}\left(\frac{1+\cos \mathrm{I}}{2}\right)^2\left(\frac{\eta}{\sigma}\right)^2$	$2(\gamma-\eta)$	2χ + ○
μ	20	$\frac{23}{16}\mathrm{G}\left(\frac{1+\cos \mathrm{I}}{2}\right)^2\left(\frac{\eta}{\sigma}\right)$	$2(\gamma-2\sigma+\eta)$	2χ + (2☽ − ○)

In the following Tables (I′) and (II′) the numerical values of R, so far as they can be calculated, and of n are given. Table (I′) corresponds to Table (I.), (II′) to (III.) In Table (II′) two values of R bracketed together are given for each term—one for the mean maximum value of I, and the other for the mean minimum value of I. These values of I are taken as 28° 36′ 7″ and 18° 18′ 31″ respectively.

TABLE (I′)

$$T=\frac{3}{2}\frac{S}{E}P^{3}a=24\ 6746.$$

Distinguishing Letters	No of term	R−T.	n Speed in degrees per mean solar hour
	1	$-\frac{1}{8}$K	0
	2	0396 K	0
	3.	·008385 K	0410686
	4.	·0396 K	·0821372
P.	5.	·3816 F	14·9589314
	6.	·0224 F	14 9178628
	7.	·0032 F	15
	8.	·01644 F	15·1232058
K.	9.	·3651 F	15·0410686
	10.	·009185 F	15 0821372
	11.	·009185 F	15
S.	12.	·4595 G	30
T.	13.	·02697 G	29 9589314
R.	14.	·003853 G	30 0410686
	15.	·0008534 G	30·1642744
K.	16.	·0396 G	30·0821372

TABLE (II′).

$$T' = \frac{3}{2}\frac{M}{E}P'^3 a = 53{\cdot}6045.$$

Distinguishing Letters	No of term	R−T′.	n Speed in degrees per mean solar hour
	1.	$-\frac{1}{6}$K	0
	2	05729 K ·02467 K	0
	3.	02745 K 02745 K	0 5490165
	4.	·05729 K ·02467 K	1 0980330
O.	5.	·4495 F 3062 F	13·9430356
Q.	6.	·08637 F 05883 F	13 3940191
	7.	·01234 F ·008405 F	14·4920521
	8.	·02921 F ·007951 F	16·1391016
K.	9.	·4203 F ·2982 F	15 0410686
J.	10.	·03461 F 02456 F	15·5900851
	11.	·03461 F ·02456 F	14·4920521
M.	12.	·4750 G ·4408 G	28·9841042
N.	13.	·09127 G ·08471 G	28·4350877
L.	14.	·01304 G ·01210 G	29·5331207
	15.	·001862 G 0003203 G	31·1801702
K.	16.	05729 G 02467 G	30 0821372
λ.	17.	·0009144 G ·0008488 G	29·4509835
ν.	18.	·006400 G ·005942 G	28 5172249
S.	19.	·0003324 G ·0003084 G	30·0000000
μ.	20.	·007647 G 007094 G	27·9682084

Third Report of the Committee, consisting of Dr Brunton, *F.R.S.*, *and* Dr. Pye-Smith, *appointed to investigate the Conditions of Intestinal Secretion and Movement.*

The first part of the task of your Committee respected the comparative effect on intestinal secretion of various salts locally applied, and the action of other drugs, either mingled with these or injected into the blood, in modifying their action. This was completed in our first Report, in which we gave an account of our experiments on the local action of purgative salts, and stated that atropia has not the same inhibitory effect on intestinal secretion which it has on that of the submaxillary gland.

Secondly, we ascertained last year that the same "paralytic" secretion which Moreau observed in dogs and rabbits occurs under similar conditions in cats, and, further, that this effect is not produced by division of the pneumogastric nerves and cervical sympathetic cord, nor by section of the splanchnics and spinal cord, and that all these sources of nervous supply may be cut off, and both semilunar ganglia extirpated, without paralytic secretion following. We ventured to anticipate that the inhibitory centre sought would be found in the smaller ganglia of the solar plexus. We had also noticed that hyperæmia or hæmorrhage of the intestinal mucous membrane does not follow either upon division of the splanchnics or upon extirpation of the lumbar portion of the spinal cord, but frequently occurs when both these operations have been performed together.

This year your Committee have succeeded in proving positively that the conclusion they had reached by the method of exclusion is correct, namely, that the paralytic secretion of Moreau may be produced by extirpation of the smaller ganglia of the solar plexus, including those which are found in the superior mesenteric plexus.

We have also ascertained that removal of these ganglia is rarely followed by hyperæmia or hæmorrhage of the intestinal mucous membrane.

Thirdly, turning to the last section of our investigation, the movements of the intestine, we have obtained fairly conclusive evidence that its peristaltic movement (in the cat) is unaffected by irritation of the distal end of the divided splanchnics, but is called forth by stimulation of their proximal part.

The conclusions, then, to which your Committee have been led may be thus summed up:—

1. Application of various soda and potash salts to the intestinal mucous membrane produces a more or less profuse secretion, that caused by sulphate of magnesia, acetate of potash, sulphate of soda, and tartrate of potash and soda being most abundant.

2. The presence (in the intestine or in the blood) of atropia, morphia, chloral, &c. does not prevent the above action of sulphate of magnesia.

3. The secretory nerves of the intestines have the small ganglia of the solar and superior mesenteric plexuses for their centres; hence secretion is unaffected by section of the splanchnics, the vagi, or the dorso-lumbar part of the cord.

4. Destruction of the lumbar part of the cord, after extirpation of the solar plexus, produces hæmorrhage or hyperæmia of the intestinal mucous membrane, which is absent after division of the splanchnics, destruction of the

semilunar ganglia and solar plexus, or division of the mesenteric nerves themselves.

5. The splanchnic nerves are, as usually admitted, the vasomotor nerves of the intestines, but have no centrifugal fibres to their muscular coats, and can only indirectly affect them by diminishing their supply of blood.

6. The splanchnics are the afferent nerves which regulate peristalsis of the intestine, the efferent stimulus probably reaching its intraparietal ganglia through the lumbar cord and abdominal sympathetic.

The following are the details of the experiments made this year. With those described in our two preceding Reports, they make up a total of more than a hundred, as the basis of the above conclusions.

In the first series we continued and completed the experiments in our last Report, undertaken to ascertain the nervous centre, separation from which produces the "paralytic" secretion of Moreau. Starting from the negative results with which we concluded our research last year, it will be seen that, of the thirteen cases in which we removed the solar or the superior mesenteric plexus, paralytic secretion resulted abundantly in Nos. 1, 2, 3, and 13, where both were removed. The same effect was produced in Nos. 7, 8, and 10, where the splanchnics and semilunar ganglia were left intact, and only the smaller (inferior) ganglia of the solar plexus, with the superior mesenteric offset from it, were excised. In No. 5, and also in No. 14, the paralytic secretion was likewise present, though less abundant. In four cases (Nos. 4, 6, 9, and 11) there was little or none, but in three of these cases the dissection, by which we verified in each case the completeness of the lesion produced, showed that the plexus had only been torn away from the artery without complete excision of its ganglia, and in No. 11 the superior mesenteric plexus was simply cut across, so as to separate it from the semilunar ganglia and splanchnics, with the superior part of the solar plexus. Thus the negative results here, like those of last year's experiments, confirm our present conclusions. In No. 12 there was enough fluid found to fill the loop moderately, but the rest of the intestine was empty; dissection did not show any defect in the previous operation, nor had there been hæmorrhage, diarrhœa, or sickness. It will, however, be noted that in this experiment less time had elapsed than in any of the others (2 instead of 3½, 4, 5, or 6 hours), and this fact, taken with the observation of the most abundant secretion having followed the longest period between the excision of the plexus and the animal being killed (see No. 7), may perhaps explain the scanty secretion in this instance.

The concluding series of experiments are on a difficult subject, which has already engaged the attention of Ludwig and his pupils, of Lister, Pflüger, Wundt, Von Basch, and other distinguished physiologists. Whether we are justified in the conclusions which we have drawn we must wait for time to determine, and will only add that we are well aware of the many possible fallacies which attend the inquiry, as well as of the conflicting results of previous investigators.

P.S.—Since this Report was presented (Glasgow, 1876), one of us, who was fortunate in securing the requisite Certificate from the Home Office, has obtained fresh results confirming those of the second series of these experiments.—July 1877.

SUMMARY OF EXPERIMENTS [*].

First Series.

No.	Lesion.	Hours.	Result.
1	Excision of both semilunar ganglia and of the superior mesenteric plexus. Two 4-inch loops ligatured at beginning of jejunum and at end of ileum.	5	Upper loop empty, mucous membrane dry. Between the loops 20 c. c. of mucus and serum without bile or blood, mucous membrane moist. Lower loop contained a little of the same. Serous coat congested.
2	Same as 1. Superior mesenteric artery accidentally wounded and ligatured. Diarrhœa before end of operation. Loops empty before ligature.	4½	Cat vomited shortly before it was killed. Peritoneal congestion of intestines. Duodenum, mucous membrane congested, hæmorrhage into the gut. Upper loop, 5 c. c. of pale opalescent fluid[†]. Between the loops 40 c. c. of similar but rather thicker fluid, with a few streaks of blood which was accidentally mixed with it. Lower loop, 8 c. c. of thin glairy fluid. Mucous membrane congested throughout.
3[‡]	Same as 1.	4	Upper loop, 8 c. c. of bile-stained fluid. Between loops, 45 c. c. of turbid fluid. Lower loop, 8 c. c. of clear glairy fluid. Mucous membrane normal.
4	Mesenteric plexus alone excised.	3–4	All the loops empty, except a tapeworm in the ileum. Mucous membrane pale. [On dissection, it was found that the operation had been very imperfectly performed, so that the greater part of the plexus was intact.]
5	Same as 4. Three 4-inch loops in jejunum, middle and lower ileum tied.	4	Duodenum partly contracted, with some fluid contents. Upper loop, 7 c. c. of fluid. Middle, 5 c. c., with small tapeworm. Lower, 4 c. c. (darker) and a tapeworm. Intestine injected outside throughout, mucous membrane in upper loop injected, in the others normal.

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[*] The animals used throughout were cats, and the anæsthetic employed was chloroform.

[†] The laboratory assistant, who had been a soldier in India, remarked that this fluid was just like the rice-water stools he had seen in cholera epidemics.

[‡] This cat was white, with grey eyes, and was deaf.

TABLE (*continued*).

No.	Lesion	Hours	Result
6.	Same as 4 .	3⅓	Upper loop, tapeworm and round worms Middle empty Lower, tapeworms Mucous membrane pale and bile-stained [The superior mesenteric plexus was found to have been only detached without excision]
7	Same as 4	6	Upper loop, a little clear fluid Between loops, 52 c c of yellowish, rather turbid and tenacious fluid Lower empty Mucous membrane pale No worms Serous coat injected
8	Same as 4 Two loops tied, one in upper jejunum 8 in, the other in lower ileum 6 in	5	Upper loop, 21 c c of turbid and blood-stained fluid, tapeworm and round worms Between loops, 28 c c of similar fluid, no worms Lower loop, 22 c c of serous fluid, no worms Mucous membrane pale throughout, and viscera anæmic
9	Same as 4	4 ...	The whole intestine empty Mucous membrane dry One small tapeworm Clot in peritoneum from oozing of a small vessel [Some of the plexus was found only separated from the artery, but not destroyed]
10.	Same as 4 One loop tied in lower ileum 18 in. Lacteal full	4	Jejunum and upper ileum (25 in), 27 c c yellow turbid fluid Loop 45 c c same fluid Mucous membrane rather pale No worms Congested externally, and serous effusion in peritoneum
11	Superior mesenteric divided from the solar plexus, but no ganglia removed	3.. ...	Negative result.
12.	Superior mesenteric plexus divided, and both semilunar ganglia excised	2	Only a few c c of glairy fluid in the loop
13.	Solar plexus excised Superior mesenteric artery isolated by excision of its plexus Three loops as in No 5.	12 ...	The cat was sick during the night, and passed mucous stools After it was killed next morning there was no peritonitis found, but effusion of chyle from puncture of a lacteal during the operation. Upper loop filled with dark brown fluid Middle the same, but not so abundant. Lower, as upper. Mucous membrane pale, œdematous, and covered with thin tenacious mucus Two round worms and a tapeworm.

SECOND SERIES.

14.—Cat under chloroform. Abdomen opened, and intestines exposed for 5 or 6 minutes to the air. No movement. The interrupted current from DuBois Reymond's induction-coil was used in this and the succeeding experiments. Electrodes placed under *left splanchnic*. Secondary coil at 25, no effect; at 15, doubtful; at 10, rapid anæmia of stomach and small intestines and of a large mesenteric gland. No movement. Coil at 7: continued anæmia, which now extended to the kidneys; no movement; after removal of the irritation, the anæmia continued and even increased for a short time in the intestines, the kidneys recovering their normal vascularity more quickly.

After the intestines had regained their normal vascularity, the coil was put at 5, and the *left splanchnic* again irritated for 5 minutes. The effect was the same, but much less decided than before. After the current was stopped, the intestines became rapidly hyperæmic. The irritation once more applied, with the coil at 0, anæmia only ensued after 30 seconds. No movement of the intestines. Ten minutes later the current was applied to the *right splanchnic* with the secondary coil at 25: no effect. Coil moved to 15: anæmia of stomach and intestines; slight movement, which had begun before the first irritation, now ceased. Current stopped: normal vascularity recovered; peristalsis began again, and became rather active; ecchymosis apparent under the tunic of the right kidney.

Intestines at rest: vascularity normal. *Right splanchnic* irritated with coil at 10: after two minutes, anæmia of stomach and some coils of intestine. Moved to 5, the large arteries became evidently smaller, though the vascularity of the viscera was still only partially affected. After two minutes more no movement.

The *solar plexus*, including the semilunar ganglia, was now *excised*, and the *superior mesenteric artery isolated*. The intestines were somewhat hyperæmic, the kidneys normal, peristalsis rather active. An upper and lower loop of 8 in. each ligatured as before. Coil at 15: electrodes applied to both splanchnics so as to irritate them at the same time: no anæmia; movement slightly increased. Coil at 10: no anæmia; movement considerably increased. Coil at 5: active peristalsis of stomach and intestines, doubtful decrease of vascularity.

The *left splanchnic* was next divided, and the electrodes applied to its *proximal end*, with the coil at 25. The movements which were going on before continued active, while the coil was moved to 15, 10, and 5. Slight anæmia appeared with the coil at 15, and did not increase. After the current was stopped, the intestines continued their movements, and quickly recovered a normal or perhaps slightly excessive vascularity. Fresh irritation a few minutes later (of the proximal end of the left splanchnic) produced no change in vascularity or in movement of the intestine.

The cat died several hours later without having vomited. The greater part of the small intestine contained only a moderate quantity of fluid, but the lower loop was filled with serum and thick white mucus. No worms. On dissection the right semilunar ganglion and solar plexus adjacent were found to be imperfectly removed: otherwise the operation had succeeded.

15.—Cat under chloroform. Abdomen opened and electrodes put on the *left splanchnic*, with coil at 25: no peristalsis, moderate injection. Current on: at first apparent slight increase of vascularity, but when the coil was moved to 15, pallor, with contraction of the branches of the superior mesenteric artery, became marked. No movement of stomach or intestines took place.

16.—Cat chloroformed and put into a bath of ·75 per cent. salt solution at 90° to 100° F., with the trachea opened so as to allow of complete immersion*. After electrodes had been put on *both splanchnics*, with the intestines at rest and moderately injected, the current was put on with a commutator, so as to pass through both nerves at once with the coil at 25, shifted after two minutes to 15, and then to 5 and to 0, but without visible effect.

17.—Cat chloroformed and abdomen opened. Intestines pale. Pregnant uterus No peristalsis. *Both splanchnics divided Proximal end* of *right* irritated, with the coil at 25 After two minutes the uterus began moving: on breaking the circuit this ceased gradually. The same occurred on applying the electrodes in the same way to the *left splanchnic*, the intestines still remaining motionless and their injection not varying The narcosis was kept only moderately deep, the tail constantly moving At every third or fourth expiration there was a strong contraction of the abdominal walls with relaxed diaphragm (effort at vomiting).

Electrodes were then applied to (the proximal end of) *both splanchnics*, and the current passed through both at once. Coil at 25. no change: intestines drawn out from abdomen so as to bring the greater part into view; they were motionless and moderately vascular. Coil at 15, current on: active peristalsis began, and soon spread to all the small intestines, the uterus also moved as before; vascularity of the viscera not altered After three minutes the current was stopped, and the movements quickly ceased Repeated with the coil at 5 and at 10 no effect was produced, but general movements of the voluntary muscles ensued from escape of the current

The animal was then placed in a bath of 75 per cent of salt solution at about 90° F, arranged so as to cover the abdomen but allow of respiration, and *both splanchnics* were irritated with the coil at 10 no effect.

Removed from bath *no movement Left splanchnic* (proximal end as before) irritated with coil at 15. After 30 seconds active peristalsis began in the colon, the uterus, and some folds of the small intestine Moved to 10, peristalsis appeared in fresh folds, which ceased on stopping the current.

Electrodes on *right splanchnic*: coil at 15. no movement Current on after a few seconds active peristalsis began in the stomach, spread to the intestines, and by the end of the first minute all the small intestines were in movement, as well as the uterus, the colon not participating. Moved up to 10, increased activity of motion. the colon continuing quiet, and the vascularity of the viscera not affected, except as the tight contraction of the gut produced transient pallor. On stopping the current, peristalsis ceased within two minutes

The electrodes were then applied to the *superior mesenteric plexus*, which was isolated for the purpose Coil at 15, current on slight movement occurred, but not constantly, the vascularity of the small intestine was distinctly, though only moderately diminished. Applied to the *renal plexus* no change was visible, but after removal the kidney increased in vascularity. Applied lastly to the nerves going to the *spleen*, that viscus shrunk from 5½ to 5 inches in length.

18—Cat under chloroform. *Both splanchnics divided*, and *distal end* of *left* placed on electrodes, the intestines being anæmic and at rest. Coil at 25, current on: after 90 seconds there was very slight and limited peristalsis, but no other change. With the coil at 15 there was no movement, but the intestines were more vascular than before, which may, however, have been due to sponging with warm water to remove some blood.

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* This precaution (in which we followed Sanders Ezn and Houckgeest) we found to be useless for the object in view, and do not recommend it to future investigators.

Experiment repeated with the animal in the bath. There was then no change in vascularity, and no movement, except very slight peristalsis in a single coil. (This cat had suffered from hæmorrhage, owing to the liver being bruised in restoring it by artificial respiration. The fact was discovered after the animal was killed, and explained its feeble state during the experiments.)

19.—Cat chloroformed. *Both splanchnics divided.* Electrodes placed on *proximal end* of *left*, and the animal immersed in the bath at 100° F. There was at first active peristalsis, and after this had ceased, stimulation, with the coil at 25, produced no effect on the vascularity or movement of the intestines. Repeated out of the water there was still no movement, but the intestines became less vascular while the current passed, and then somewhat hyperæmic.

Stimulation of the proximal end of the *right splanchnic* out of the bath produced active peristalsis. The vascularity varied irregularly, and probably independently, with moderate injection after the current was stopped.

On the *left splanchnic* being again irritated after an interval (with the coil still at 25), peristalsis, which had become very languid, was distinctly increased. The intestines became pale during the strong contraction of each coil, but otherwise their vascularity was unaffected.

Stimulation of the *splenic plexus* reduced the length of the spleen from 3½ to 3¼ inches.

Report of the Committee, consisting of A. VERNON HARCOURT, Professor GLADSTONE, *and* Dr. ATKINSON, *appointed for the purpose of collecting and suggesting subjects for Chemical Research.*

BEFORE entering upon the task of forming a list of subjects, the members of the Committee took opportunities of discussing the question privately with other chemists, and found in many cases considerable doubts as to the advisability of such a proceeding. Instead, therefore, of at once inviting suggestions for research, the Committee considered it desirable to ascertain the opinion of English chemists generally as to the feasibility of the proposed scheme. The following Circular was accordingly sent to about fifty chemists, who were either those of the highest official standing, or who were known to be engaged in research:—

"BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

"April 24, 1876.

"DEAR SIR,—At the last Meeting of the British Association a Committee was appointed, consisting of Mr. Vernon Harcourt, Dr Gladstone, and Dr E. Atkinson, with power to add to their number, to collect and suggest subjects for chemical research.

"When the matter was discussed by the Committee of the Chemical Section, at whose instance the above-named Committee was appointed, it was thought that a step might be taken towards the organization of chemical inquiry by the formation and publication of a list of subjects to be suggested by the leading chemists of our own country, and, if possible, of other countries also, from which younger chemists wishing to undertake a research might select a subject with the assurance that it was considered new and important

"It was thought also that such a list, however meagre and inadequate it might be at the outset, would tend to increase as soon as the plan became more widely known, and might ultimately, if chemists of other countries were willing to take part, become an important feature in a general organization of chemical research

"A chemist undertaking the investigation of any one of the suggested subjects would send word to the editors of the list, and might be placed in communication with the chemist by whom the subject was suggested Each issue of the list, which might be republished at frequent intervals in some of the chemical journals, would state which subjects had been already undertaken and by whom, and thus the waste of labour which sometimes occurs through simultaneous work on the same subject would be prevented.

"It has, however, been objected that chemists are not likely to be so prodigal of their ideas as such a scheme supposes, and may prefer keeping the subjects of research which have suggested themselves to their minds for their own or their pupils' investigation The answer to this would seem to depend upon the answer to the general question, whether the supply of ideas or suggestions for research existing in the minds of the leading chemists at the present day does or does not largely exceed the number of skilled hands at their disposal

"Before, therefore, proceeding to invite you and others to suggest subjects to be placed upon the proposed list, the Committee are desirous of learning whether in your judgment the scheme is likely to succeed, and whether, if the attempt to form such a list is made, you would be willing to contribute to it, they would also be glad of any opinions in reference to the matter with which you may favour them

"We are, dear Sir,
"Yours faithfully,
"A G Vernon Harcourt,
"J. H. Gladstone,
"E. Atkinson"

"P S. Please address your answer, Dr. Atkinson, York Town, Surrey."

To this Circular only eight written replies were received, of which four may be classed as favourable, namely, those from Mr. Abel, President of the Chemical Society, Prof. Mills, Mr. Bolas, and Mr. R. Warington; three as adverse to the scheme, viz. from Dr. Joule, Mr. Hartley, and Mr. Groves, the latter embodying the views of Dr. Stenhouse; and one as doubtful from Mr. Buckton.

Among the objections raised to the proposed scheme perhaps the following have been the most general:—

That suggestions for subjects of research would only be needed by, or be useful to, students and beginners, and that such men would generally be under the guidance of Professors, who would provide them with subjects; that the suggestion of a subject is generally its least part, that what students really want is guidance and instruction in the art of investigation, that any one who had originality and power to make a satisfactory research would also be able to find subjects for himself, that facilities and material appliances for research, together with the means of living for those thus engaged, were more pressing wants; that any one contributing suggestions for research would reserve for his own use the best of them, that is to say, those most likely to give important and satisfactory results.

Of the letters received, the Committee may perhaps give the following from Mr. Buckton and from Dr. Joule —

"Wycombe, Haslemere

"I believe that the result of chemical inquiry would be greater and more important in nature if the suggestions made by your Committee could be efficiently carried out. I must confess, however, that my fears shape themselves very much after the fashion expressed by paragraph 5 of your Circular.

"Original workers, I believe, always are under the hope that eventually time and opportunity will present themselves, so that they will allow them personally to work out their brightest and most promising ideas. If this be so, but few of such will find a place in the contemplated list. Again, hesitation might be felt amongst some lest the most promising subjects should be negatived by the results of an inexperienced hand.

"The number of skilled hands in our laboratories is certainly larger than formerly, yet probably in this country latterly the harvest of original work has not been in due proportion to this number.

"If so, the steps proposed towards the organization of chemical inquiry by way of a list will, I think, be beneficial.

"G. B. Buckton."

"Manchester, May 4, 1876.

"We know that the scientific faculty is of slow growth in the case of any individual student. He becomes interested in a particular line of inquiry, and in pursuing it becomes further interested by the acquisition of new facts. The original inquiry will naturally ramify, and there will be a completeness about his work and also an accuracy which could not be expected from that done as it were to order. I think, too, that the mere suggestions of a research may tend to make it unpalatable to many minds. We know that mere suggestions have in some instances been claimed as discoveries. On this account many would feel some delicacy in even suggesting an inquiry, necessarily accompanied by the suggestion of the expected result, simply because it looks like a forestalling to some extent of the merit of the actual labourer.

"Then, in order to be in a position to suggest, a scientific man must have mentally worked out the methods and anticipated the results of the proposed train of investigation, and would doubtless prefer to work it out himself, or, at any rate, to have the work done by his pupils under his immediate superintendence—first, because he naturally wishes that full justice should be done to the subject from his own point of view, and second, because he considers himself to a certain extent in the light of a proprietor.

"I do not think it desirable to use any extra stimulus to induce students to work. If their own tastes and abilities and information do not lead them to find a vein of knowledge and work it, the application of such stimulus would probably result in the accumulation of incomplete and erroneous results to the hindrance of real scientific advancement.

"James P. Joule."

In order that the proposed scheme should be successful it ought to meet with very general support. This has been far from being the case, and therefore the Committee have not thought it advisable to proceed further in the matter.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

Address by Professor Sir WILLIAM THOMSON, *LL.D., M.A., F.R.S., President of the Section.*

A CONVERSATION which I had with Professor Newcomb one evening last June, in Professor Henry's drawing-room in the Smithsonian Institution, Washington, has forced me to give all my spare thoughts ever since to Hopkins's problem of Precession and Nutation, assuming the earth a rigid spheroidal shell filled with liquid. Six weeks ago, when I landed in England after a most interesting trip to America and back, and became painfully conscious that I must have the honour to address you here to-day, I wished to write an Address of which science in America should be the subject. I came home, indeed, vividly impressed with much that I had seen both in the Great Exhibition of Philadelphia and out of it, showing the truest scientific spirit and devotion, the originality, the inventiveness, the patient persevering thoroughness of work, the appreciativeness, and the generous open-mindedness and sympathy, from which the great things of science come.

Θελω λεγειν Ατρειδας
Θελω δε Καδμον ᾳδειν

I wish I could speak to you of the veteran Henry, generous rival of Faraday in electromagnetic discovery; of Peirce, the founder of high mathematics in America; of Bache, and of the splendid heritage he has left to America and to the world in the United States Coast Survey; of the great school of astronomers which followed—Gould, Newton, Newcomb, Watson, Young, Alvan Clarke, Rutherford, Draper (father and son); of Commander Belknap and his great exploration of the Pacific depths by pianoforte-wire with imperfect apparatus supplied from Glasgow, out of which he forced a success in his own way; of Captain Sigsbee, who followed with like fervour and resolution, and made further improvements in the apparatus by which he has done marvels of easy quick and sure deep-sea sounding in his little surveying-ship 'Blake;' and of the admirable official spirit which makes such men and such doings possible in the United States Naval Service. I would like to tell you, too, of my reasons for confidently expecting that American hydrography will soon supply the data from tidal observations long ago asked of our Government in vain by a Committee of the British Association, by which the amount of the earth's elastic yielding to the distorting influence of sun and moon will be measured; and of my strong hope that the Compass Department of the American Navy will repay the debt to France, England, and Germany, so appreciatively acknowledged in their reprint of the works of Poisson, Airy, Archibald Smith, Evans, and the Liverpool Compass Committee, by giving in return a fresh marine survey of terrestrial magnetism, to supply the navigator with data for correcting his compass without sights of sun or stars.

Can I go on to Precession and Nutation without a word of what I saw in the Great Exhibition of Philadelphia? In the U.S. Government part of it, Professor Hilgard showed me the measuring rods of the U.S. Coast Survey, with their beautiful mechanical appliances for end measurement, by which the three great base-lines of Maine, Long Island, and Georgia were measured with about the same accuracy as the most accurate scientific measurers, whether of Europe or America, have attained in comparing two metre or yard measures.

In the United States telegraphic department I saw and heard Elisha Gray's splendidly worked out Electric Telephone actually sounding four messages simultaneously on the Morse code, and clearly capable of doing yet four times as many with very moderate improvements of detail, and I saw Edison's Automatic Telegraph delivering 1015 words in 57 seconds: this done by the long neglected electro-chemical method of Bain, long ago condemned in England to the helot work of recording from a relay, and then turned adrift as needlessly delicate for that. In the Canadian Department I heard 'To be or not to be . . . there's the rub' through an electric telegraph wire; but, scorning monosyllables, the electric articulation rose to higher flights, and gave me passages taken at random from the New-York newspapers:— 'S.S. "Cox" has arrived' (I failed to make out the S.S. "Cox"); 'The City of New York,' 'Senator Morton,' 'The Senate has resolved to print a thousand extra copies,' 'The Americans in London have resolved to celebrate the coming fourth of July.' All this my own ears heard, spoken to me with unmistakable distinctness by the thin circular disk armature of just such another little electromagnet as this which I hold in my hand. The words were shouted with a clear and loud voice by my colleague judge, Professor Watson, at the far end of the telegraph-wire, holding his mouth close to a stretched membrane, such as you see before you here, carrying a little piece of soft iron, which was thus made to perform in the neighbourhood of an electromagnet in circuit with the line motions proportional to the sonorific motions of the air. This, the greatest by far of all the marvels of the electric telegraph, is due to a young countryman of our own, Mr. Graham Bell, of Edinburgh and Montreal and Boston, now becoming a naturalized citizen of the United States. Who can but admire the hardihood of invention which devised such very slight means to realize the mathematical conception that, if electricity is to convey all the delicacies of quality which distinguish articulate speech, the strength of its current must vary continuously and as nearly as may be in simple proportion to the velocity of a particle of air engaged in constituting the sound?

The Patent Museum of Washington (an institution of which the nation is justly proud) and the beneficent working of the United States patent laws deserve notice in the Section of the British Association concerned with branches of science to which nine tenths of all the useful patents of the world owe their foundations. I was much struck with the prevalence of patented inventions in the Exhibition: it seemed to me that every good thing deserving a patent was patented. I asked one inventor of a very good invention, "Why don't you patent it in England?" He answered, "The conditions in England are too onerous." We certainly are far behind America's wisdom in this respect. If Europe does not amend its patent laws (England in the opposite direction to that proposed in the Bills before the last two sessions of Parliament) America will speedily become the nursery of useful inventions for the world.

I should tell you also of "Old Probs'" weather-warnings, which cost the nation 250,000 dollars a year: money well spent say the western farmers, and not they alone; in this the whole people of the United States are agreed; and though Democrats or Republicans playing the "economical ticket" may for half a session stop the appropriations for even the United-States Coast Survey, no one would for a moment think of proposing to starve "Old Prob," and now that 80 per cent of his probabilities have proved true, and General Myers has for a month back ceased to call his daily forecasts "probabilities" and has begun to call them indications, what will the western farmers call him this time next year?

And the United-States Naval Observatory, full of the very highest science, under the command of Admiral Davis! If, to get on to Precession and Nutation, I had resolved to omit telling you that I had there, in an instrument for measuring photographs of the Transit of Venus shown me by Professor Harkness (a young Scotsman attracted into the United-States Naval Service), seen, for the first time in an astronomical observatory, a geometrical slide, the verdict on the disaster on board the 'Thunderer,' published while I am writing this address, forbids me to keep any such resolution, and compels me to put the question—Is there in the British Navy, or in a British steamer, or in a British land-boiler another safety-valve so constructed that by any possibility, at any temperature or under any stress, it can jam? and to say that if there is, it must be instantly corrected or removed.

I ought to speak to you, too, of the already venerable Harvard University, the Cambridge of America, and of the Technological Institute of Boston, created by William Rogers, brother of my late colleague in this University (Glasgow), Henry Rogers, and of the Johns Hopkins University of Baltimore, which with its youthful vigour has torn Sylvester from us, has utilized the genius and working-power of Roland for experimental research, and three days after my arrival in America sent for the young Porter Poinier to make him a Fellow, but he was on his deathbed, in New York, "begging his physicians to keep him alive just to finish his book, and then he would be willing to go." Of his book, 'Thermodynamics,' we may hope to see at least a part, for much of the manuscript and good and able friends to edit it are left, but the appointment to a Fellowship in the Johns Hopkins University came a day too late to gratify his noble ambition.

But the stimulus of intercourse with American scientific men left no place in my mind for framing or attempting to frame a report on American science. Disturbed by Newcomb's suspicions of the earth's irregularities as a time-keeper, I could think of nothing but precession and nutation, and tides and monsoons, and settlements of the equatorial regions, and meltings of the polar ice. Week after week passed before I could put down two words which I could read to you here today; and so I have nothing to offer you for my Address but

Review of Evidence regarding the Physical Condition of the Earth: its internal Temperature, the Fluidity or Solidity of its interior Substance, the Rigidity, Elasticity, Plasticity, of its External Figure, and the Permanence or Variability of its Period and Axis of Rotation.

The evidence of a high internal temperature is too well known to need any quotation of particulars at present. Suffice it to say that below the uppermost ten metres stratum of rock or soil sensibly affected by diurnal and annual variations of temperature there is generally found a gradual increase of temperature downwards, approximating roughly in ordinary localities to an average rate of 1° Centigrade per thirty metres of descent, but much greater in the neighbourhood of active volcanoes and certain other special localities, of comparatively small area, where hot springs and perhaps also sulphurous vapours prove an intimate relationship to volcanic quality. It is worthy of remark in passing that, so far as we know at present, there are no localities of exceptionally *small* rate of augmentation of underground temperature, and none where temperature diminishes at any time through any considerable depth downwards below the stratum sensibly influenced by summer heat and winter cold. Any considerable area of the earth of, say, not less than a kilometre in any horizontal diameter, which for several thousand years had been covered by snow or ice, and from which the ice had melted away and left an average surface temperature of 13° Cent., would, during 900 years, show a decreasing temperature for some depth down from the surface; and 3600 years after the clearing away of the ice would still show residual effect of the ancient cold, in a half rate of augmentation of temperature downwards in the upper strata, gradually increasing to the whole normal rate, which would be sensibly reached at a depth of 600 metres.

By a simple effort of geological calculus it has been estimated that 1° per 30 metres gives 1000° per 30,000 metres, and 3333° per 100 kilometres. This arithmetical result is irrefragable; but what of the physical conclusion drawn from it with marvellous frequency and pertinacity, that at depths of from 30 to 100 kilometres the temperatures are so high as to melt all substances composing the earth's upper crust? It has been remarked, indeed, that if observation showed any diminution or augmentation of the rate of increase of underground temperature in great depths, it would not be right to reckon on the uniform rate of 1° per 30 metres or thereabouts down to 30 or 60 or 100 kilometres. "But observation has shown nothing of the kind, and therefore surely it is most consonant with inductive philosophy to admit no great deviation in any part of the earth's solid crust from the rate of increase proved by observation as far as the greatest depths to which we have reached!" Now I have to remark upon this argument that the greatest depth to which we have reached in observations of underground temperature is scarcely one kilometre, and that if a 10-per-cent diminution of the rate of augmentation of underground temperature downwards were found at a depth of one kilometre, this would demonstrate* that within the last 100,000 years the upper surface of the earth must have been at a higher temperature than that now found at the depth of one kilometre Such a result is no doubt to be found by observation in places which have been overflown by lava in the memory of man or a few thousand years further back, but if, without going deeper than a kilometre, a 10-per-cent diminution of the rate of increase of temperature downwards were found for the whole earth, it would limit the whole of geological history to within 100,000 years, or, at all events, would interpose an absolute barrier against the continuous descent of life on the earth from earlier periods than 100,000 years ago Therefore, although search in particular localities for a diminution of the rate of augmentation of underground temperature in depths of less than a kilometre may be of intense interest, as helping us to fix the dates of extinct volcanic actions which have taken place within 100,000 years or so, we know enough from thoroughly sure geological evidence not to expect to find it, except in particular localities, and to feel quite sure that we shall not find it under any considerable portion of the earth's surface If we admit as possible any such discontinuity within 900,000 years, we might be prepared to find a sensible diminution of the rate at three kilometres depth, but not at any thing less than 30 kilometres if geologists validly claim as much as 90,000,000 of years for the length of the time with which their science is concerned Now this implies a temperature of 1000° Cent at the depth of 30 kilometres, allows something less than 2000° for the temperature at 60 kilometres, and does not require much more than 4000° Cent at any depth however great, but does require at the great depths a temperature of, at all events, not less than about 4000° Cent. It would not take much "hurrying up" of the actions with which they are concerned to satisfy geologists with the more moderate estimate of 50,000,000 of years. This would imply at least about 3000° Cent for the limiting temperature at great depths If the actual substance of the earth, whatever it may be, rocky or metallic, at depths of from 60 to 100 kilometres, under the pressure actually there experienced by it, can be solid at temperatures of from 3000° to 4000°, then we may hold the former estimate (90,000,000) to be as probable as the latter (50,000,000), so far as evidence from underground temperature can guide us. If 4000° would melt the earth's substance at a depth of 100 kilometres, we must reject the former estimate though we might still admit the latter; if 3000° would melt the substance at a depth of 60 kilometres, we should be compelled to conclude that 50,000,000 of years is an over-estimate. Whatever may be its age, we may be quite sure the earth is solid in its interior; not, I admit, throughout its whole volume, for there certainly are spaces in volcanic regions occupied by liquid lava; but whatever portion of the whole mass is liquid, whether the waters of the ocean or melted matter in the interior, these portions are small in comparison with the whole, and we must utterly reject any geological hypothesis which, whether for explaining underground heat or ancient upheavals and subsidences of the solid crust, or earthquakes, or existing volcanoes, assumes the solid earth to be a shell of 30, or 100, or 500, or 1000 kilometres thickness, resting on an interior liquid mass

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* For proof of this and following statements regarding underground heat, I refer to "Secular Cooling of the Earth," Transactions of the Royal Society of Edinburgh, 1862; and Thomson and Tait's 'Natural Philosophy,' Appendix D.

This conclusion was first arrived at by Hopkins, who may therefore properly be called the discoverer of the earth's solidity. He was led to it by a consideration of the phenomena of precession and nutation, and gave it as shown to be highly probable, if not absolutely demonstrated, by his confessedly imperfect and tentative investigation. But a rigorous application of the perfect hydrodynamical equations leads still more decidedly to the same conclusion.

I am able to say this to you now in consequence of the conversation with Professor Newcomb, to which I have already alluded. Admitting fully my evidence for the rigidity of the earth from the tides, he doubted the argument from precession and nutation. Trying to recollect what I had written on it fourteen years ago in a paper on the "Rigidity of the Earth," published in the Transactions of the Royal Society, my conscience smote me, and I could only stammer out that I had convinced myself that so-and-so and so-and-so, at which I had arrived by a non-mathematical short cut, were true. He hinted that viscosity might suffice to render precession and nutation the same as if the earth were rigid, and so vitiate the argument for rigidity. This I could not for a moment admit, any more than when it was first put forward by Delaunay. But doubt entered my mind regarding the so-and-so and so-and-so, and I had not completed the night journey to Philadelphia which hurried me away from our unfinished discussion before I had convinced myself that they were grievously wrong. So now I must request as a favour that each one of you on going home will instantly turn up his or her copies of the 'Transactions of the Royal Society' for 1862 and of Thomson and Tait's 'Natural Philosophy,' vol. i., and draw the pen through §§ 23-31 of my paper on the "Rigidity of the Earth" in the former, and through every thing in §§ 847, 848, 849 of the latter which refers to the effect on precession and nutation of an elastic yielding of the earth's surface.

When those passages were written I knew little or nothing of vortex motion, and until my attention was recalled to them by Professor Newcomb I had never once thought of this subject in the light thrown upon it by the theory of the quasi-rigidity induced in a liquid by vortex motion, which has of late occupied me so much. With this fresh light a little consideration sufficed to show me that (although the old obvious conclusion is of course true, that, if the inner boundary of the imagined rigid shell of the earth were rigorously spherical, the interior liquid could experience no precessional or nutational influence from the pressure on its bounding surface, and therefore if homogeneous could have no precession or nutation at all, or if heterogeneous only as much precession and nutation as would be produced by attraction from without in virtue of non-sphericity of its surfaces of equal density, and therefore the shell would have enormously more rapid precession and nutation than it actually has—forty times as much, for instance, if the thickness of the shell is 60 kilometres) a very slight deviation of the inner surface of the shell from perfect sphericity would suffice, in virtue of the quasi rigidity due to vortex motion, to hold back the shell from taking sensibly more precession than it would give to the liquid, and to cause the liquid (homogeneous or heterogeneous) and the shell to have sensibly the same precessional motion as if the whole constituted one rigid body. But it is only because of the very long period (26,000 years) of precession, in comparison with the period of rotation (one day), that a very slight deviation from sphericity would suffice to cause the whole to move as if it were a rigid body. A little further consideration showed me —

(1) That an ellipticity of inner surface equal to $\frac{1}{26,000 \times 365}$ would be too small, but that an ellipticity of one or two hundred times this amount would not be too small to compel approximate equality of precession throughout liquid and shell.

(2) That with an ellipticity of interior surface equal to $\frac{1}{400}$, if the precessional motion were 20,000 times as great as it is, the motion of the liquid would be very different from that of a rigid mass rigidly connected with the shell.

(3) That with the actual forces and the supposed interior ellipticity of $\frac{1}{300}$, the lunar nineteen-yearly nutation might be affected to about five per cent. of its amount by interior liquidity.

(4) Lastly, that the lunar semiannual nutation must be largely, and the lunar fortnightly nutation enormously affected by interior liquidity.

But although so much could be foreseen readily enough, I found it impossible to discover without thorough mathematical investigation what might be the characters and amounts of the deviations from a rigid body's motion which the several cases of precession and nutation contemplated would present. The investigation, limited to the case of a homogeneous liquid enclosed in an ellipsoidal shell, has brought out results which I confess have greatly surprised me. When the interior ellipticity of the shell is just too small, or the periodic speed of the disturbance just too great to allow the motion of the whole to be sensibly that of a rigid body, the deviation first sensible renders the precessional or nutational motion of the shell smaller than if the whole were rigid, instead of greater, as I expected. The amount of this difference bears the same proportion to the actual precession or nutation as the fraction measuring the periodic speed of the disturbance (in terms of the period of rotation as unity) bears to the fraction measuring the interior ellipticity of the shell, and it is remarkable that this result is independent of the thickness of the shell, assumed, however, to be small in proportion to the earth's radius. Thus in the case of precession the effect of interior liquidity would be to diminish the periodic speed of the precession in the proportion stated, in other words, it would add to the precessional period a number of days equal to the multiple of the rotational period equal to the number whose reciprocal measures the ellipticity. Thus, in the actual case of the earth, if we still take $\frac{1}{300}$ as the ellipticity of the inner boundary of the supposed rigid shell, the effect would be to augment by 300 days the precessional period of 2600 years, or to diminish by about $\frac{1''}{60}$ the annual precession of about 51'', an effect which I need not say would be wholly insensible. But on the lunar nutation of 18·6 years period, the effect of interior liquidity would be quite sensible; 18·6 years being twenty three times 300 days, the effect would be to diminish the axes of the ellipse which the earth's pole describes in this period each by $\frac{1}{23}$ of its own amount. The semiaxes of this ellipse, calculated on the theory of perfect rigidity from the very accurately known amount of precession, and the fairly accurate knowledge which we have of the ratio of the lunar to the solar part of the precessional motion, are 9''·22 and 6''·86, with an uncertainty not amounting to one half per cent. on account of want of perfect accuracy in the latter part of data. If the true values were less each by $\frac{1}{23}$ of its own amount, the discrepance might have escaped detection, or might *not* have escaped detection, but certainly could be found if looked for. So far nothing can be considered as absolutely proved with reference to the interior solidity of the earth from precession and nutation; but now think of the solar semiannual and the lunar fortnightly nutations. The period of each of these is less than 300 days. Now the hydrodynamical theory shows that, irrespectively of the thickness of the shell, the nutation of the crust would be zero if the period of the nutational disturbance were 300 times the period of rotation (the ellipticity being $\frac{1}{300}$), if the nutational period were any thing between this and a certain smaller critical value depending on the thickness of the crust, the nutation would be negative; if the period were equal to this second critical value, the nutation would be infinite, and if the period were still less, the nutation would be again positive. Further, the 183 days period of the solar nutation falls so little short of the critical 300 days that the amount of the nutation is not sensibly influenced by the thickness of the crust, is negative and equal in absolute value to $\frac{61}{39}$ (being the reciprocal of $\frac{300}{183}-1$) times what the amount would be were the earth solid throughout. Now this amount, as calculated in the 'Nautical Almanac,' makes 0''·55 and 0''·51 the semiaxes of the ellipse traced by the earth's axis round its mean position; and if the true nutation placed the earth's axis on the opposite side of an ellipse having 0''·86 and 0''·81 for its semiaxes, the discrepance could not possibly have escaped detection. But, lastly, think of the lunar fortnightly nutation. Its period is $\frac{1}{20}$ of 300 days, and its amount, calculated in the 'Nautical Almanac' on the theory of complete solidity, is such that the greater semiaxis of the approximately circular ellipse described by the pole is 0″·0325. Were the crust infinitely thin this nutation would be negative, but its amount nineteen times that corresponding to solidity This would make the greater semiaxis of the approximately circular ellipse described by the pole amount to 19×0″·0885, which is 1″·7. It would be negative and of some amount between 1″·7 and infinity, if the thickness of the crust were any thing from zero to 120 kilometres. This conclusion is absolutely decisive against the geological hypothesis of a thin rigid shell full of liquid

But interesting in a dynamical point of view as Hopkins's problem is, it cannot afford a decisive argument against the earth's interior liquidity. It assumes the crust to be perfectly stiff and unyielding in its figure This, of course, it cannot be, because no material is infinitely rigid, but, composed of rock and possibly of continuous metal in the great depths, may the crust not, as a whole, be stiff enough to practically fulfil the condition of unyieldingness? No, decidedly it could not: on the contrary, were it of continuous steel and 500 kilometres thick, it would yield very nearly as much as if it were india-rubber to the deforming influences of centrifugal force and of the sun's and moon's attractions Now although the full problem of precession and nutation, and, what is now necessarily included in it, tides, in a continuous revolving liquid spheroid, whether homogeneous or heterogeneous, has not yet been coherently worked out, I think I see far enough towards a complete solution to say that precession and nutations will be practically the same in it as in a solid globe, and that the tides will be practically the same as those of the equilibrium theory From this it follows that precession and nutations of the solid crust, with the practically perfect flexibility which it would have even though it were 100 kilometres thick and as stiff as steel, would be sensibly the same as if the whole earth from surface to centre were solid and perfectly stiff. Hence precession and nutations yield nothing to be said against such hypotheses as that of Darwin*, that the earth as a whole takes approximately the figure due to gravity and centrifugal force, because of the fluidity of the interior and the flexibility of the crust But, alas for this "attractive sensational idea that a molten interior to the globe underlies a superficial crust, its surface agitated by tidal waves, and flowing freely towards any issue that may here and there be opened for its outward escape" (as Poulett Scrope called it)! the solid crust would yield so freely to the deforming influence of sun and moon that it would simply carry the waters of the ocean up and down with it, and there would be no sensible tidal rise and fall of water relatively to land

The state of the case is shortly this —The hypothesis of a perfectly rigid crust containing liquid violates physics by assuming preternaturally rigid matter, and violates dynamical astronomy in the solar semiannual and lunar fortnightly nutations; but tidal theory has nothing to say against it On the other hand, the tides decide against any crust flexible enough to perform the nutations correctly with a liquid interior, or as flexible as the crust must be unless of preternaturally rigid matter

But now thrice to slay the slain: suppose the earth this moment to be a thin crust of rock or metal resting on liquid matter, its equilibrium would be unstable! And what of the upheavals and subsidences? They would be strikingly analogous to those of a ship which has been rammed—one portion of crust up and another down, and then all down. I may say, with almost perfect certainty, that whatever may be the relative densities of rock, solid and melted, at or about the temperature of liquefaction, it is, I think, quite certain that cold solid rock is denser than hot melted rock; and no possible degree of rigidity in the crust could prevent it from breaking in pieces and sinking wholly below the liquid lava. Something like this may have gone on, and probably did go on, for thousands of years after solidification commenced—surface-portions of the melted material losing heat, freezing, sinking immediately, or growing to thicknesses of a few metres, when the surface would be cool and the whole solid dense enough to sink. "This process must go on until the sunk portions of crust build up from the bottom a sufficiently close-ribbed skeleton or frame to allow fresh incrustations to remain, bridging across the now small areas of lava pools or lakes.

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* "Observations on the Parallel Roads of Glen Roy and other parts of Lochaber in Scotland, with an attempt to prove that they are of marine origin," Transactions of the Royal Society for Feb. 1839, p. 81

"In the honeycombed solid and liquid mass thus formed there must be a continual tendency for the liquid, in consequence of its less specific gravity, to work its way up; whether by masses of solid falling from the roofs of vesicles or tunnels and causing earthquake-shocks, or by the roof breaking quite through when very thin, so as to cause two such hollows to unite or the liquid of any of them to flow out freely over the outer surface of the earth, or by gradual subsidence of the solid owing to the thermodynamic melting which portions of it under intense stress must experience, according to my brother's theory. The results which must follow from this tendency seem sufficiently great and various to account for all that we learn from geological evidence of earthquakes, of upheavals and subsidences of solid, and of eruptions of melted rock."*

Leaving altogether now the hypothesis of a hollow shell filled with liquid, we must still face the question, how much does the earth, solid throughout, except small cavities or vesicles filled with liquid, yield to the deforming (or tide-generating) influences of sun and moon? This question can only be answered by observation. A single infinitely accurate spirit-level or plummet far enough away from the sea to be not sensibly affected by the attraction of the rising and falling water would enable us to find the answer. Observe by level or plummet the changes of direction of apparent gravity relatively to an object rigidly connected with the earth, and compare these changes with what they would be were the earth perfectly rigid, according to the known masses and distances of sun and moon. The discrepance, if any is found, would show distortion of the earth, and would afford data for determining the dimensions of the elliptic spheroid into which a non-rotating globular mass of the same dimensions and elasticity as the earth would be distorted by centrifugal force if set in rotation, or by tide generating influences of sun or moon. The effect on the plumb-line of the lunar tide-generating influence is to deflect it towards or from the point of the horizon nearest to the moon, according as the moon is above or below the horizon. The effect is zero when the moon is on the horizon or overhead, and is greatest in either direction when the moon is 45° above or below the horizon. When this greatest value is reached, the plummet is drawn from its mean position through a space equal to $\frac{1}{12,000,000}$ of the length of the thread. No ordinary plummet or spirit-level could give any perceptible indication whatever of this effect, and to measure its amount it would be necessary to be able to observe angles as small as $\frac{1}{120,000,000}$ of the radian, or about $\frac{1}{600}''$. Siemens's beautiful hydrostatical multiplying level may probably supply the means for doing this. Otherwise at present no apparatus exists within small compass by which it could be done. A submerged water-pipe of considerable length, say 12 kilometres, with its two ends turned up and open, might answer. Suppose, for example, the tube to lie north and south, and its two ends to open into two small cisterns, one of them, the southern for example, of half a decimetre diameter (to escape disturbance from capillary attraction), and the other of two or three decimetres diameter (so as to throw nearly the whole rise and fall into the smaller cistern). For simplicity, suppose the time of observation to be when the moon's declination is zero. The water in the smaller or southern cistern will rise from its lowest position to its highest position while the moon is rising to maximum altitude, and fall again after the moon crosses the meridian till she sets, and it will rise and fall again through the same range from moonset to moonrise. If the earth were perfectly rigid, and if the locality is in latitude 45°, the rise and fall would be half a millimetre on each side of the mean level, or a little short of half a millimetre if the place is within 10° north or south of latitude 45°. If the air were so absolutely quiescent during the observations as to give no varying differential pressure on the two water-surfaces to the amount of $\frac{1}{100}$ millimetre of water or $\frac{1}{1400}$ of mercury, the observation would be satisfactorily practicable, as it would not be difficult by aid of a microscope to observe the rise and fall of the water in the smaller cistern to $\frac{1}{100}$ of a millimetre; but no such quiescence of the atmosphere could be expected at any time, and it is probable that the variations of the water-level due to difference of the barometric pressure at the two ends would, in all ordinary weather, quite overpower the small effect of the lunar tide-generating motive. If, however, the two cisterns, instead of being open to the atmosphere, were connected air-tightly by a return-pipe with no water in it, it is probable that the observation might be successfully made: but Siemens's level or some other apparatus on a similarly small scale would probably be preferable to any elaborate method of obtaining the result by aid of very long pipes laid in the ground; and I have only called your attention to such an ideal method as leading up to the natural phenomenon of tides.

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* "Secular Cooling of the Earth," Transactions of the Royal Society of Edinburgh, 1862 (W. Thomson), and Thomson and Tait's 'Natural Philosophy,' §§ (*ee*), (*ff*).

Tides in an open canal or lake of 12 kilometres length would be of just the amount which we have estimated for the cisterns connected by submerged pipe, but would be enormously more disturbed by wind and variations of atmospheric pressure. A canal or lake of 240 kilometres length in a proper direction and in a suitable locality would give but 10 millimetres rise and fall at each end, an effect which might probably be analyzed out of the much greater disturbance produced by wind and differences of barometric pressure, but no open liquid level short of the *ingens æquor*, the ocean, will probably be found so well adapted as it for measuring the absolute value of the disturbance produced on terrestrial gravity by the lunar and solar tide-generating motive. But observations of the diurnal and semidiurnal tides in the ocean do not (as they would on smaller and quicker levels) suffice for this purpose, because their amounts differ enormously from the equilibrium-values on account of the smallness of their periods in comparison with the periods of any of the grave enough modes of free vibration of the ocean as a whole. On the other hand, the lunar fortnightly declinational and the lunar monthly elliptic and the solar semiannual and annual elliptic tides have their periods so long that their amounts must certainly be very approximately equal to the equilibrium-values. But there are large annual and semiannual changes of sea-level, probably both differential (on account of wind and differences of barometric pressure and differences of temperature of the water) and absolute, depending on rainfall and the melting away of snow and return evaporation, which altogether swamp the small semiannual and annual tides due to the sun's attraction. Happily, however, for our object there is no meteorological or other disturbing cause which produces periodic changes of sea-level in either the fortnightly declinational or the monthly elliptic period; and the lunar gravitational tides in these periods are therefore to be carefully investigated in order that we may obtain the answer to the interesting question, how much does the earth as an elastic spheroid yield to the tide-generating influence of sun or moon? Hitherto in the British-Association Committee's reductions of Tidal Observations we have not succeeded in obtaining any trustworthy indications of either of these tides. The St.-George's pier landing-stage pontoon, unhappily chosen for the Liverpool tide-gauge, cannot be trusted for such a delicate investigation: the available funds for calculation were expended before the long-period tides for Hilbre Island could be attacked, and three years of Kurrachee gave our only approach to a result. Comparisons of this with an indication of a result of calculations on West Hartlepool tides, conducted with the assistance of a grant from the Royal Society, seem to show possibly no sensible yielding, or perhaps more probably some degree of yielding, of the earth's figure. The absence from all the results of any indication of a 18·6 yearly tide (according to the same law as the other long-period tides) is not easily explained without assuming or admitting a considerable degree of yielding.

Closely connected with the question of the earth's rigidity, and of as great scientific interest and of even greater practical moment, is the question, How nearly accurate is the earth as a timekeeper? and another of, at all events, equal scientific interest, How about the permanence of the earth's axis of rotation?

Peters and Maxwell, about 35 and 25 years ago, separately raised the question, How much does the earth's axis of rotation deviate from being a principal axis of inertia? and pointed out that an answer to this question is to be obtained by looking for a variation in latitude of any or every place on the earth's surface in a period of 300 days The model before you illustrates the travelling round of the instantaneous axis relatively to the earth in an approximately circular cone whose axis is the principal axis of inertia, and relatively to space in a cone round a fixed axis. In the model the former of these cones, fixed relatively to the earth, rolls internally on the latter, supposed to be fixed in space Peters gave a minute investigation of observations at Pulkova in the years 1841–42, which seem to indicate at that time a deviation amounting to about $\frac{3}{10}''$ of the axis of rotation from the principal axis. Maxwell, from Greenwich observations of the years 1851–54, found seeming indications of a very slight deviation, something less than half a second, but differing altogether in phase from that which the deviation indicated by Peters, if real and permanent, would have produced at Maxwell's later time. On my begging Professor Newcomb to take up the subject, he kindly did so at once, and undertook to analyze a series of observations suitable for the purpose which had been made in the United-States Naval Observatory, Washington A few weeks later I received from him a letter referring me to a paper by Dr. Nysen, of Pulkova Observatory, in which a similar negative conclusion as to constancy of magnitude or direction in the deviation sought for is arrived at from several series of the Pulkova observations between the years 1842 and 1872, and containing the following statement of his conclusions:—

"The investigation of the ten-month period of latitude from the Washington prime vertical observations from 1862 to 1867 is completed, indicating a coefficient too small to be measured with certainty The declinations with this instrument are subject to an annual period which made it necessary to discuss those of each month separately. As the series extended through a full five years, each month thus fell on five nearly equidistant points of the period If x and y represent the coordinates of the axis of instantaneous rotation on June 30, 1864, then the observations of the separate months give the following values of x and y:—

	x.	Weight	y.	Weight.
January	−0″·35	10	+0″·32	
February	−0·03	14	+0·09	
March	+0·17	10	+0·16	
April	+0·44	5	+0·05	
May	+0·08	16	+0·02	
June	−0·01	14	−0·01	
July	−0·05	14	0·00	
August	−0·24	14	+0·29	
September	+0·18	14	+0·21	
October	+0·13	14	−0·01	
November	+0·08	17	−0·20	
December	−0·08	16	−0·08	
Mean	0·01±0·03		+0·05±0·03	

"Accepting these results as real, they would indicate a radius of rotation of the instantaneous axis amounting, at the earth's surface, to 5 feet and a longitude of the point in which this axis intersects the earth's surface near the North Pole, such that on July 11, 1864, it was 180° from Washington, or 103° east of Greenwich. The excess of the coefficient over its probable error is so slight that this result cannot be accepted as any thing more than a consequence of the unavoidable errors of observation."

From the discordant character of these results we must not, however, infer that the deviations indicated by Peters, Maxwell, and Newcomb are unreal. On the contrary, any that fall within the limits of probable error of the observations ought properly to be regarded as real. There is, in fact, a *vera causa* in the temporary changes of sea-level due to meteorological causes, chiefly winds, and to meltings of ice in the polar regions and return evaporations, which seems amply sufficient to account for irregular deviations of from $\frac{1}{2}''$ to $\frac{1}{20}''$ of the earth's instantaneous axis from the axis of maximum inertia, or, as I ought rather to say, of the axis of maximum inertia from the instantaneous axis.

As for geological upheavals and subsidences, if on a very large scale of area, they must produce, on the period and axis of the earth's rotation, effects comparable with those produced by changes of sea-level equal to them in vertical amount. For simplicity, calculating as if the earth were of equal density throughout, I find that an upheaval of all the earth's surface in north latitude and east longitude and south latitude and west longitude with equal depression in the other two quarters, amounting at greatest to ten centimetres, and graduating regularly from the points of maximum elevation to the points of maximum depression in the middles of the four quarters, would shift the earth's axis of maximum moment of inertia through 1'' on the north side towards the meridian of 90° W. longitude, and on the south side towards the meridian of 90° E longitude. If such a change were to take place suddenly, the earth's instantaneous axis would experience a sudden shifting of but $\frac{1}{300}''$ (which we may neglect), and then, relatively to the earth, would commence travelling, in a period of 306 days, round the fresh axis of maximum moment of inertia The sea would be set into vibration, one ocean up and another down through a few centimetres, like water in a bath set aswing. The period of these vibrations would be from 12 to 24 hours, or at most a day or two, their subsidence would probably be so rapid that after at most a few months they would become insensible Then a regular 306-days period tide of 11 centimetres from lowest to highest would be to be observed, with gradually diminishing amount from century to century, as through the dissipation of energy produced by this tide the instantaneous axis of the earth is gradually brought into coincidence with the fresh axis of maximum moment of inertia If we multiply these figures by 3600, we find what would be the result of a similar sudden upheaval and subsidence of the earth to the extent of 360 metres above and below previous levels. *It is not impossible that in the very early ages of geological history such an* action as this, and the consequent 400-metres tide producing a succession of deluges every 306 days for many years, may have taken place, but it seems more probable that even in the most ancient times of geological history the great world-wide changes, such as the upheavals of the continents and subsidences of the ocean-beds from the general level of their supposed molten origin, took place gradually through the thermodynamic melting of solids and the squeezing out of liquid lava from the interior, to which I have already referred. A slow distortion of the earth as a whole would never produce any great angular separation between the instantaneous axis and axis of maximum moment of inertia for the time being. Considering, then, the great facts of the Himalayas and Andes, and Africa and the depths of the Atlantic, and America and the depths of the Pacific, and Australia, and considering further the ellipticity of the equatorial section of the sea-level estimated by Capt. Clarke at about $\frac{1}{19}$ of the mean ellipticity of meridional sections of the sea-level, we need no brush from the comet's tail (a wholly chimerical cause which can never have been put forward seriously except in ignorance of elementary dynamical principles) to account for a change in the earth's axis, we need no violent convulsion producing a sudden distortion on a great scale, with change of the axis of maximum moment of inertia followed by gigantic deluges, and we may not merely admit, but assert as highly probable, that the axis of maximum inertia and axis of rotation, always very near one another, may have been in ancient times very far from their present geographical position, and may have gradually shifted through 10, 20, 30, 40, or more degrees without at any time any perceptible sudden disturbance of either land or water.

Lastly, as to variations in the earth's rotational period You all no doubt know how, in 1853, Adams discovered a correction to be needed in the theoretical calculation with which Laplace followed up his brilliant discovery of the dynamical explanation of an apparent acceleration of the moon's mean motion shown by records of ancient eclipses, and how he found that when his correction was applied the dynamical theory of the moon's motion accounted for only about half of the observed apparent acceleration, and how Delaunay in 1866 verified Adams's result and suggested that the explanation may be a retardation of the earth's rotation by tidal friction. The conclusion is that, since the 19th of March, 721 B.C., a day on which an eclipse of the moon was seen in Babylon, commencing "when one hour after her rising was fully passed," the earth has lost rather more than $\frac{1}{2,700,000}$

of her rotational velocity, or, as a timekeeper, is going slower by 11¼ seconds per annum now than then. According to this rate of retardation, if uniform, the earth at the end of a century would, as a timekeeper, be found 22 seconds behind a perfect clock, rated and set to agree with her at the beginning of the century. Newcomb's subsequent investigations in the lunar theory have on the whole tended to confirm this result; but they have also brought to light some remarkable apparent irregularities in the moon's motion, which, if real, refuse to be accounted for by the gravitational theory without the influence of some unseen body or bodies passing near enough to the moon to influence her mean motion. This hypothesis Newcomb considers not so probable as that the apparent irregularities of the moon are not real, and are to be accounted for by irregularities in the earth's rotational velocity. If this is the true explanation, it seems that the earth was going slow from 1850 to 1862, so much as to have got behind by seven seconds in these twelve years, and then to have begun going faster again so as to gain eight seconds from 1862 to 1872. So great an irregularity as this would require somewhat greater changes of sea-level, but not many times greater than the British Association Committee's reductions of tidal observations for several places in different parts of the world allow us to admit to have possibly taken place. The assumption of a fluid interior, which Newcomb suggests, and the flow of a large mass of the fluid "from equatorial regions to a position nearer the axis," is not, from what I have said to you, admissible as a probable explanation of the remarkable acceleration of rotational velocity which seems to have taken place about 1862, but happily it is not necessary. A settlement of 14 centimetres in the equatorial regions, with corresponding rise of 28 centimetres at the poles (which is so slight as to be absolutely undiscoverable in astronomical observatories, and which would involve no change of sea-level absolutely disproved by reductions of tidal observations hitherto made), would suffice. Such settlements must occur from time to time, and a settlement of the amount suggested might result from the diminution of centrifugal force due to 150 or 200 centuries' tidal retardation of the earth's rotational speed.

MATHEMATICS.

Sur les Mouvements apériodiques des Systèmes de Points Matériels.

By M. VALENTINO CERRUTI.

A short communication referring to a system of points subject to their mutual action and to that of fixed exterior points.

Sur les Systèmes de Sphères et les Systèmes de Droites.

By Professor LUIGI CREMONA.

Cette communication avait pour objet d'exposer une méthode pour transformer les *congruences* (systèmes doublement infinis) de droites, contenues dans un complexe linéaire donné, de manière qu'à chaque droite de la congruence corresponde un point d'une surface, et vice-versa. La méthode résulte de la combinaison des transformations de l'espace à trois dimensions, exposées par l'auteur dans les 'Annali di Matematica' (série 2ᵉ, tome 5ᵉ), avec la transformation, donnée par MM. Noether et Lie, d'un complexe linéaire en l'espace ordinaire (point-espace). Suivant cette transformation, les plans de l'espace correspondent aux congruences linéaires du complexe donné qui contiennent une droite fixe; et aux autres congruences linéaires du même complexe correspondent les sphères de l'espace ordinaire. La méthode exposée dans la communication donne toutes les transformations d'un complexe linéaire en l'espace ordinaire, telles qu'aux congruences linéaires contenant une droite fixe correspondent des surfaces d'un ordre donné. En particulier, on obtient toutes les congruences (non-linéaires, contenues dans le complexe donné) qui sont susceptibles d'être représentées sur un plan, de manière que chaque droite de la congruence ait pour image un point déterminé du plan et que, vice-versa, chaque point du plan corresponde à une droite unique de la congruence. Si l'on transforme le plan par les polaires réciproques de Poncelet, les images des droites de la congruence seront les droites du plan représentatif.

On Graphical Interpolation and Integration.
By GEORGE H. DARWIN, *M.A., Fellow of Trin. Coll., Cambridge.*

Suppose a number of points A, B, C, &c. are given on equidistant ordinates of a curve, and that it is desired to draw a curve through them. This may be best done by interpolating intermediate points. Let *a*, *b*, *c*, &c. be ordinates halfway between A and B, B and C, &c. Join AB, BC, &c. along the whole curve, and let the ordinates *a*, *b*, *c*, &c. intersect AB, BC, CD, &c. in *f*, *g*, *h*, &c. Join AC, BD, CE, &c., and so on along the whole curve, and let the ordinates B, C, D, &c. intersect AC, BD, CE, &c. in F, G, H, &c. Then the rule for interpolating on the ordinates *a*, *b*, *c*, &c. is—produce *af* to *l*, and make $fl = \frac{1}{4}$ BF; produce *bg* to *m*, and make $gm = \frac{1}{4}$ CG, and so on. In carrying this out practically, several of the above lines need not actually be drawn.

This rule may be proved from the properties of the circle of curvature, which passes through three consecutive points, such as A, B, C. It gives results correct as far as second differences. A slightly different result will be obtained by working along the curve in the opposite direction: to obtain a better result work both ways along the curve, and choose the points which lie halfway between the discrepant readings. The result so given is correct as far as third differences.

In determining the approximate value of a definite integral it is often convenient to find a geometrical construction for giving a line proportional to the function to be integrated, and then to determine half a dozen values of the function. But the question then arises as to how these terms are to be combined, so as to give the required integral—whether by the rules given by the calculus of finite differences, or by the simpler rule of taking the mean of the extremes and adding it together with all the rest, and multiplying by the common difference. Each ordinate or term is affected by an error, and it may be that the theoretically best rule may give a higher probable error to the result than the more imperfect rule. If, for example, we have seven ordinates, each subject to a probable error *e*, Weddle's rule (see Boole's Calc. Fin. Diff.) would give a result subject to a probable error 2·846 *he*, whilst the worse rule only gives a probable error 2·345 *he*, where *h* is the common difference. It must therefore remain indeterminate whether more is gained by a diminished probable error or by a better rule of quadratures. The question could only be determined by some knowledge of the amount of probable error of each ordinate, and of the abruptness of the curvature of the curve*.

On certain Determinants. *By* J. W. L. GLAISHER, *M.A., F.R.S.*

The author gave the following results:—

I. If P_n denote the number of partitions of *n* into the elements 1, 2, 3, 4, ..., repetitions not excluded, then

$$P_n = \begin{vmatrix} +1, & -1, & \cdot\,, & \cdot\,, & \cdot\,, & \cdot\,, & \cdot\,, & \cdot\,, & \ldots \\ +1, & +1, & -1, & \cdot\,, & \cdot\,, & \cdot\,, & \cdot\,, & \cdot\,, & \ldots \\ \cdot\,, & +1, & +1, & -1, & \cdot\,, & \cdot\,, & \cdot\,, & \cdot\,, & \ldots \\ \cdot\,, & \cdot\,, & +1, & +1, & -1, & \cdot\,, & \cdot\,, & \cdot\,, & \ldots \\ -1, & \cdot\,, & \cdot\,, & +1, & +1, & -1, & \cdot\,, & \cdot\,, & \ldots \\ \cdot\,, & -1, & \cdot\,, & \cdot\,, & +1, & +1, & -1, & \cdot\,, & \ldots \\ -1, & \cdot\,, & -1, & \cdot\,, & \cdot\,, & +1, & +1, & -1, & \ldots \\ \cdot\,, & -1, & \cdot\,, & -1, & \cdot\,, & \cdot\,, & +1, & +1, & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \end{vmatrix} \quad (n \text{ rows})$$

where the first column is

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* The paper is printed *in extenso* in the 'Messenger of Mathematics,' vol. vi. (January 1877).

$$+1, +1, 0, 0, -1, 0, -1, 0, 0, 0, 0, +1, 0, 0, +1, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0,$$
$$-1, 0, 0, 0, 0, 0, 0, 0, 0, +1, \ldots.$$

viz. between two unities of the same sign the numbers of zeros follow the law 0, 1, 2, 3, 4 . . , while the numbers of zeros between two unities of opposite sign follow the law 2, 4, 6, 8 . . , the second column is the same as the first column, but lowered one line, and with -1 as the top constituent; the third column is the same as the second line, but lowered one line, and with zero as the top constituent; the fourth column is the same as the third column, but lowered one line, and with zero as the top constituent, and so on

For example:—

$$P_3 = \begin{vmatrix} +1, & -1, & \cdot \\ +1, & +1, & -1 \\ \cdot\,, & +1, & +1 \end{vmatrix} = 3$$

which is right, since $3 = 1+1+1 = 1+2$.

II. If $\psi(n)$ be the sum of the divisors of n, then

$$\psi(n) = \begin{vmatrix} +1, & -1, & \cdot\,, & \cdot\,, & \cdot\,, & \cdot\,, & \cdot\,, & \ldots \\ +2, & +1, & -1, & \cdot\,. & \cdot\,, & \cdot\,, & \cdot\,, & \ldots \\ \cdot\,, & +1, & +1, & -1, & \cdot\,, & \cdot\,, & \cdot\,, & \ldots \\ \cdot\,, & \cdot\,, & +1, & +1, & -1, & \cdot\,, & \cdot\,. & \ldots \\ -5, & \cdot\,, & \cdot\,, & +1, & +1, & -1, & \cdot\,, & \ldots \\ \cdot\,, & -1, & \cdot\,, & \cdot\,, & +1, & +1, & -1, & \ldots \\ -7, & \cdot\,, & -1, & \cdot\,, & \cdot\,, & +1, & +1, & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \end{vmatrix} (n \text{ rows})$$

where all the constituents remain as before, except those in the first column, in which the rth constituent appears multiplied by r. Thus the non-zero constituents in the first column are the pentagonal numbers, of the form $\tfrac{1}{2}n(3n \pm 1)$.

For example:—

$$\psi(3) = \begin{vmatrix} +1, & -1, & \cdot \\ +2, & +1, & -1 \\ \cdot\,, & +1, & +1 \end{vmatrix} = 4$$

which is right, since $\psi(3) = 1+3 = 4$.

III. Consider the determinant

$$\nabla = \begin{vmatrix} 2, & 3, & 4, & 5, & 6, & \ldots n \\ 1, & \cdot\,, & 2, & \cdot\,, & 3, & \ldots \\ \cdot\,, & 1, & \cdot\,, & \cdot\,, & 2, & \ldots \\ \cdot\,, & \cdot\,, & 1, & \cdot\,, & \cdot\,, & \ldots \\ \cdot\,, & \cdot\,, & \cdot\,, & 1, & \cdot\,, & \ldots \\ \cdot\,, & \cdot\,, & \cdot\,, & \cdot\,, & 1, & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots & \end{vmatrix} (n-1 \text{ rows})$$

wherein the top line contains the natural numbers beginning with 2 and ending with n; the second line is obtained by dividing the constituents of the top line by 2, and entering the quotient or zero according as each constituent is or is not divisible by 2; the third line is obtained by dividing the constituents of the top line by 3, and entering the quotient or zero according as each constituent is or is not divisible by 3, and so on.

Then $\nabla = 0$ if n is divisible by any square factor, and $\nabla = (-)^{n+N}n$ if n is a simple product of prime factors; viz. $\alpha\beta\gamma \ldots \xi$, where $\alpha, \beta, \gamma \ldots \xi$ are different primes, and N denotes the number of prime divisors of n, unity included.

For example.—

$$\begin{vmatrix} 2, & 3, & 4, & 5, & 6 \\ 1, & \cdot\,, & 2, & \cdot\,, & 3 \\ \cdot\,, & 1, & \cdot\,, & \cdot\,, & 2 \\ \cdot\,, & \cdot\,, & 1 & \cdot\,, & \cdot \\ \cdot\,, & \cdot\,, & \cdot\,, & 1, & \cdot \\ \cdot\,, & \cdot\,, & \cdot\,, & \cdot\,, & 1 \end{vmatrix} = (-)^{6+3}6$$

which is easily verified.

On a Series Summation leading to an Expression for the Theta Function as a Definite Integral. By J. W. L. GLAISHER, *M.A., F.R.S.*

By means of the formula giving the resolution of $1+x^n$ into its linear factors and of the equation

$$\frac{\sin(a-x)\sin(a+x)}{\sin^2 a}=\left\{1-\frac{x^2}{a^2}\right\}\left\{1-\frac{x^2}{(a-\pi)^2}\right\}\left\{1-\frac{x^2}{(a+\pi)^2}\right\}$$
$$\left\{1-\frac{x^2}{(a-2\pi)^2}\right\}\left\{1-\frac{x^2}{(a+2\pi)^2}\right\}\ldots$$

it can be shown that

$$\left\{1+\frac{x^{2n}}{a^{2n}}\right\}\left\{1+\frac{x^{2n}}{(a-b)^{2n}}\right\}\left\{1+\frac{x^{2n}}{(a+b)^{2n}}\right\}\left\{1+\frac{x^{2n}}{(a-2b)^{2n}}\right\}\left\{1+\frac{x^{2n}}{(a+2b)^{2n}}\right\}\ldots$$
$$=2^{-n}\left(\operatorname{cosec}\frac{\pi a}{b}\right)^{2n}\mathrm{P}_1\mathrm{P}_3\mathrm{P}_5\ldots\mathrm{P}_{n-1}\text{ if } n \text{ be even}$$

and

$$=2^{-n}\left(\operatorname{cosec}\frac{\pi a}{b}\right)^2\left(\cosh\frac{2\pi x}{b}-\cos\frac{2\pi a}{b}\right)\mathrm{P}_1\mathrm{P}_3\mathrm{P}_5\ldots\mathrm{P}_{n-2}\text{ if } n \text{ be uneven,}$$

where

$$\mathrm{P}_r=\left\{\cosh\left(\frac{2\pi x}{b}\sin\frac{r\pi}{2n}\right)-\cos\frac{2\pi}{b}\left(a-x\cos\frac{r\pi}{2n}\right)\right\}$$
$$\times\left\{\cosh\left(\frac{2\pi x}{b}\sin\frac{r\pi}{2n}\right)-\cos\frac{2\pi}{b}\left(a+x\cos\frac{r\pi}{2n}\right)\right\}$$

and $\cosh x$, $\sinh x$ are written as usual for the hyperbolic cosine and sine of x, viz., $\cosh x=\frac{1}{2}(e^x+e^{-x})$, $\sinh x=\frac{1}{2}(e^x-e^{-x})$.

Taking the logarithm and differentiating, we have

$$2nx^{2n-1}\left\{\frac{1}{x^{2n}+a^{2n}}+\frac{1}{x^{2n}+(a-b)^{2n}}+\frac{1}{x^{2n}+(a+b)^{2n}}+\frac{1}{x^{2n}+(a-2b)^{2n}}\right.$$
$$\left.+\frac{1}{x^{2n}+(a+2b)^{2n}}+\&c.\right\},$$

$$=\frac{2\pi}{b}\left\{\mathrm{Q}_1+\mathrm{Q}_3+\mathrm{Q}_5\ldots+\mathrm{Q}_{n-1}\right\}\text{ if } n \text{ be even}$$

and

$$=\frac{2\pi}{b}\left\{\frac{\sinh\frac{2\pi x}{b}}{\cosh\frac{2\pi x}{b}-\cos\frac{2\pi a}{b}}+\mathrm{Q}_1+\mathrm{Q}_3\ldots+\mathrm{Q}_{n-2}\right\}\text{ if } n \text{ be uneven,}$$

where

$$\mathrm{Q}_r=\frac{\sin\frac{r\pi}{2n}\sinh\left(\frac{2\pi x}{b}\sin\frac{r\pi}{2n}\right)-\cos\frac{r\pi}{2n}\sin\frac{2\pi}{b}\left(a-x\cos\frac{r\pi}{2n}\right)}{\cosh\left(\frac{2\pi x}{b}\sin\frac{r\pi}{2n}\right)-\cos\frac{2\pi}{b}\left(a-x\cos\frac{r\pi}{2n}\right)}$$
$$+\frac{\sin\frac{r\pi}{2n}\sinh\left(\frac{2\pi x}{b}\sin\frac{r\pi}{2n}\right)+\cos\frac{r\pi}{2n}\sin\frac{2\pi}{b}\left(a+x\cos\frac{r\pi}{2n}\right)}{\cosh\left(\frac{2\pi x}{b}\sin\frac{r\pi}{2n}\right)-\cos\frac{2\pi}{b}\left(a+x\cos\frac{r\pi}{2n}\right)}$$

Using the integral,

$$2n\int_0^\infty\frac{x^{2n-1}\sin(c^n x^n)}{x^{2n}+r^{2n}}dx=\pi e^{-c^n r^n},$$

we have

$$e^{-c^n a^n}+e^{-c^n(a-b)^n}+e^{-c^n(a+b)^n}+e^{-c^n(a-2b)^n}+e^{-c^n(a+2b)^n}+\&c$$

$$=\frac{2}{b}\int_0^\infty\left\{Q_1+Q_3+Q_5\quad+Q_{n-1}\right\}\sin(c^n x^n)\,dx \text{ if } n \text{ be even,}$$

$$=\frac{2}{b}\int_0^\infty\left\{\frac{\sinh\frac{2\pi x}{b}}{\cosh\frac{2\pi x}{b}-\cos\frac{2\pi a}{b}}+Q_2+Q_4\quad+Q_{n-1}\right\}\sin(c^n x^n)\,dx \text{ if } n \text{ be uneven}$$

The exponents on the left hand side are always to be numerically negative, viz they should be written $-\sqrt{\{c^{2n}a^{2n}\}}$, $-\sqrt{\{c^{2n}(a-b)^{2n}\}}$, &c. The quantity c is redundant, and may be put equal to unity without loss of generality.

Putting $n=2$ and $c=1$ we find that

$$e^{-a^2}+e^{-(a-b)^2}+e^{-(a+b)^2}+\&c=\frac{\sqrt{2}}{b}\int_0^\infty\left\{f\left(\frac{\pi x}{b},\frac{\pi a}{b}\right)+f\left(\frac{\pi x}{b},-\frac{\pi a}{b}\right)\right\}\sin x^2\,dx,$$

where

$$f(p,q)=\frac{\sinh p\sqrt{2}+\sin(p\sqrt{2}+2q)}{\cosh p\sqrt{2}-\cos(p\sqrt{2}+2q)}.$$

Now

$$e^{-x^2}+e^{-(x-a)^2}+e^{-(x+a)^2}+\&c=\frac{\sqrt{\pi}}{a}\left\{1+2e^{-\frac{\pi^2}{a^2}}\cos\frac{2\pi x}{a}+2e^{-\frac{4\pi^2}{a^2}}\cos\frac{4\pi x}{a}+\&c\right\},$$

whence, the notation being that of the 'Fundamenta Nova,' it can be shown that

$$\Theta\left(\frac{2Kx}{\pi}\right)=\frac{\sqrt{2}}{\pi}\sqrt{\left(\frac{K}{K'}\right)}\int_0^\infty\left\{f(t,x+\tfrac{1}{2}\pi)+f(t,-x-\tfrac{1}{2}\pi)\right\}\sin\frac{K't^2}{\pi K}\,dt,$$

and therefore

$$\Theta(x)=\sqrt{\left(\frac{2}{\pi}\right)}\int_0^\infty\left\{f(\alpha t,u)+f(\alpha t,-u)\right\}\sin t^2\,dt,$$

where

$$\alpha=\frac{\pi K'}{K},\quad u=\frac{\pi}{2K}(x+K).$$

Also it can be shown that

$$\Theta(x)=\sqrt{\left(\frac{2}{\pi}\right)}\int_0^\infty\left\{\phi(\alpha t,u)+\phi(\alpha t,-u)\right\}\cos t^2\,dt,$$

where

$$\phi(p,q)=\frac{\sinh p\sqrt{2}-\sin(p\sqrt{2}+2q)}{\cosh p\sqrt{2}-\cos(p\sqrt{2}+2q)}.$$

On Parallel Motion. By W. HAYDEN.

In this paper the author noticed several cases of approximate three-bar parallel motion, founded upon certain numerical coincidences.

On Plane Cubics of the Third Class with a Double and a Single Focus

By HENRY M. JEFFERY, *M.A.*

1. The classification of class-cubics is simpler than of plane order cubics, because there are three real foci in each of the former, whereas two of the asymptotes of order cubics may be imaginary.

The three groups arranged by the coincidence of the foci have been stated in the Transactions for 1875, and the third group of spherical curves there sketched. This group ($\kappa p^3 = q$) has been also fully considered in the 'Quarterly Journal of Mathematics' for 1876, both for plane and spherical class cubics with illustrative diagrams. These two memoirs contain a complete classification of circular cubics by interpreting Boothian as Cartesian coordinates.

2. In the classification of the second group ($\kappa p^2 q = r$) the two foci will be considered fixed while the satellite-point varies. There is a certain quartic curve, the locus of the satellite point when there is a point of inflexion in the curve: if the satellite point is within this curve there will be three critic lines or bitangents; if it be on the curve there will be one bitangent and two others coinciding in a stationary tangent; if it fall beyond the bounding curve only one bitangent is possible. The critic lines or bitangents are the common tangents of three parabolæ whose foci are severally the satellite-point and the two foci of the cubic. When these parabolæ are drawn, the bitangents are obtained graphically.

The several cases of cubics of this group will be next considered according to the position of the satellite with reference to the bounding curve while all three points are finite, and subsequently, when the satellite point and the foci are, one or more, at infinity, also when the three points are collinear.

3. The group may be thus represented:—

$$\kappa p^2 q + 4\Delta^2 r = 0,$$

where $4\Delta^2 = apP + bqQ + crR$, p, q, r are the current line coordinates, and $P = ap - bq \cos C - cr \cos B$. Q, R have like values for points at infinity, as the quadrantal poles of the sides of ABC.

There are usually three critic lines, whose equations are obtained by partial differentiation:—

$$apP = 4\Delta^2 (1) \quad bqQ = 2\Delta^2 (2) \quad crR = -2\Delta^2 (3)$$

Since the condition $p = q = r$ satisfies all these equations the critic lines must touch three parabolæ, whose foci are the vertices and whose axes are the perpendiculars drawn on the sides of the triangle of reference, and, *latera recta* are four times, twice and six times its corresponding altitudes.

There are three of these critic lines, one of which is always real.

4. The Cartesian equation to the bounding curve (§ 2) or locus of the satellite-point, when there are stationary points in this group of class cubics is

$$27y^6 + 9y^4(2 + 4x + 5x^2) + y^2(1 + x)^2(-1 - 10x + 9x^2) - x(1 + 9x)(1 + x)^3 = 0,$$

or

$$\{27y^4 + 18y^2(x + 1)^2 - (9x + 1)(x + 1)\}(y^2 + x^2) = 0$$

The double focus is the origin, and the focal distance on the x axis is taken as unity, a pair of asymptotes is inclined to the diameter at angles $\pm 30°$.

The envelop of the stationary tangent is a hyperbola, and of the single (one-with-twofold) bitangent is a cubic of division V, whose double focus is at infinity.

5. Classification of the figures of class-cubics with double foci.*

I. When the satellite-point lies beyond the bounding quartic, there is one bitangent only.

The triangle of reference formed by the foci and the satellite-point is taken to be equilateral.

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* The diagrams illustrating the critical and the companion curves according to these nine capital divisions, were exhibited at the Glasgow Meeting and are ready for publication.

Let the cubic be thus denoted:—

$$p^2q=\kappa r.$$

The critical value ($\kappa=5{\cdot}1458$) determines the bitangential cubic. The cubic is bipartite or unipartite, according as $\kappa \gtrless 5{\cdot}1458$, equiharmonic if $\kappa=1{\cdot}67$ or -17, harmonic if $\kappa=-15$.

There may be two real asymptotes, since there is one bitangent in this division.

II. When the satellite-point is on the bounding sextic.

In this case there are two critical values of the parameter, corresponding to the bitangential and inflexional cubics, viz. 11·00 and 08. The curve is bipartite if $\kappa>11{\cdot}00$.

III. When the satellite is inside the quartic, and is (1) not collinear, and (2) is collinear with the foci

(1) There are three bitangents when $\kappa=47$, ·07, ·06. For higher values of κ, the curve is bipartite, between 47 and 07, unipartite; then bipartite and below the bitangential curve unipartite

There may be four asymptotes.

(2) Let the cubic be thus denoted:—

$$\lambda(1+b\xi)+(1+c\xi)(\xi^2+\eta^2)=0.$$

There are two bitangents with real and imaginary contact, as is thus shown:—

$$4+\lambda(27c^2-18bc-b^2)+4\lambda^2b^3c=0.$$

For the inflexional genus, the discriminant gives the condition

$$64b^3c=(27c^2-18bc-b^2)^2.$$

This may be resolved into two factors:—

$$(b-c)\,(b-9c)^3.$$

The first factor resolves the cubic into a point and a circle, the second factor indicates the cissoid.

$$(3+b\xi)^3+b^4(9+b\xi)\eta^2=0.$$

The satellite-point in this case is the apse in the quartic bounding curve.

IV. If the satellite-point be at infinity (1) not collinear, (2) collinear, with the two foci

(1) There are two bitangential or a single inflexional, or no bitangential form, according as the satellite lies within, upon, or beyond the quartic curve. One asymptote connects the double focus with the satellite; the other three concur in the point ($\xi=\frac{3}{2}$), the polar conic of the line at infinity degenerates into these points.

(2) There may be two asymptotes, which unite in a bitangent, for a special value of the parameter

V. If the double focus is at infinity, (1) not collinear, (2) collinear with the single focus and satellite-point.

The cubic has in all cases a bitangent, and for a particular value of the parameter two bitangents coincide in a stationary tangent at a point of inflexion. The inflexional cubic in (2) is the semicubical parabola

VI. If the single focus is at infinity (1) not collinear, (2) collinear with the double focus and satellite.

There are two bitangential forms, but no inflexional case The reciprocals in (2) are Newton's defective hyperbolæ, with diameters and double foci.

VII. If the single focus and satellite-point are both at infinity.

The curve is central and parabolic, with a cusp at infinity, but cannot have a bitangent. Its single asymptote connects the double focus with the satellite. All cubics are equiharmonic of the form

$$\lambda\xi+(\sqrt{3}\,\xi+\eta)(\xi^2+\eta^2).$$

It is thus denoted in Boothian coordinates:—

$$\lambda\xi+(a\xi+b\eta)(\xi^2+\eta^2)=0.$$

The reciprocal is Newton's central species (88).

VIII. If the double focus and satellite-point are both at infinity.

There is an inflexional form in all cases, as appears from the equation to the system.—

$$\lambda\xi^2+(a\xi+b\eta)(\xi^2+\eta^2)=0.$$

The reciprocal is a cusped cubic.

IX. If the double and single focus are both at infinity.

The line at infinity is an acu-bitangent in all cases, as is shown by the equation to the system.—

$$\lambda\xi^2(a\xi+b\eta)+(\xi^2+\eta^2)=0.$$

6. To find the asymptotes of this group of class-cubics.

Since the polar-point of an asymptote (p, q, r) lies on it, and also is at an infinite distance, the coordinates of an asymptote must satisfy two equations —

$$\phi \quad \lambda p^2q+4\Delta^2 r=0, \quad \dots\dots\dots \quad (1)$$

and that to the polar conic of the line at infinity

$$\frac{d\phi}{dp}+\frac{d\phi}{dq}+\frac{d\phi}{dr}-\lambda p(2q+p)+4\Delta^2=0, \quad \dots\dots\dots \quad (2)$$

one of whose foci, as we should anticipate, is the double focus.

The four asymptotes touch a conic, whose foci are $p=0$, $2q+p=0$. Hence also

$$r(2q+p)=pq. \quad \dots\dots\dots \quad (3)$$

The elimination of r from (2) and (3) is a quartic equation. Hence there cannot be more than four asymptotes. Its discriminant is a factor of the discriminant of the ternary cubic (1). Two imaginary asymptotes always connect the double focus with the circular points at infinity.

If the satellite (which is always on the curve) be at infinity, its connector with the double focus is an asymptote. The extremities of two asymptotes may coincide in a bitangent.

7. The centre or polar point of the line at infinity is on AB, the connector of the foci, at the distance ¼ AB from A, the double focus. AC touches the cubic in C, BC touches it where it meets the line $(\beta-\kappa\gamma=0)$.

On Spherical Class-cubics with Double Foci and Double Cyclic Arcs.

By HENRY M. JEFFERY, *M.A.*

1. This group may be denoted by line coordinates, as *in plano*.—

$$\kappa p^2q+(6V)^2r=0,$$

where

$$(6V)^2=\Sigma(a^2p^2-2bcqr\cos A),$$

and the coordinates p, q, r denote the sines of the perpendiculars from the vertices ABC on a tangent arc, and generally the symbols may denote the sines of arcs.

There are four critic values of the parameter and four bitangential values. By partial differentiation, for a critic value,

$$2\kappa pq+2raP=0; \ \kappa p^2+2rbQ=0; \ (6V)^2+2rcR=0,$$

where $P=ap-bq\cos C-cr\cos B$; and similar expressions denote Q, R, the line-coordinates of a tangent arc referred to the polar triangle as one of reference.

These conditions for a bitangent may be thus written.—

$$apP=(6V)^2 : 2bqQ=(6V)^2 : 2crR=-(6V)^2.$$

These equations denote three spherical ellipses, whose foci are in the several cases the points of reference A, B, C, and the corresponding points of reference of the polar triangle of ABC.

2. There is a sextic bounding curve, the locus of the satellite-point, when there is a point of inflexion; this curve is bipartite with an oval. If the satellite is within the oval, four critical values of the parameter yield bitangential forms of the cubic; if the satellite is on the oval, one inflexional and two bitangential cubics; if the satellite is outside the oval, two bitangential cubics. Its equation, in Gudermann's coordinates, is

$$\{(4b^2+3)y^2+(b+x)(b+3x)\}^3=27(b^2+1)(x^2+y^2)\{(x+b)^2+y^2\}^2.$$

If the two foci are a quadrant apart, $b=\infty$, and the bounding sextic becomes

$$4y^2+1=3(x+y^2)^{\frac{1}{3}}.$$

3 All cubics with double foci have double cyclic arcs.

Let the line-equation to these cubics be written

$$3\kappa a^2bp^2q+3\omega\Sigma(a^2p^2-2bcrq\cos A)=0.$$

Its equivalent point-equation may be thus arranged —

$$\begin{aligned}&(\beta^2+2\beta\gamma\cos A+\gamma^2)\{-12\beta\gamma^3\kappa^3+3\kappa^2(8\beta^2\gamma^2-\alpha^2\gamma^2+27\alpha^2\beta^2+18\alpha^2\beta\gamma\cos A\\&-20\alpha\beta\gamma^2\cos C+36\alpha\beta^2\gamma\cos B)+12\kappa[-\beta^3\gamma-\alpha\beta^3\cos B+\alpha^4\cos A-\alpha^3\gamma\cos C\\&-3\alpha\beta^2\gamma\cos C+(-\cos B+2\cos A\cos C)\alpha^3\beta+(\cos A-2\cos B\cos C)\alpha^2\beta^2\\&-(1+2\cos^2 C)\alpha^2\beta\gamma]\}+12(6V)^2\left(\frac{\sin A}{a}\right)^2\{\beta^2\gamma^2\kappa^2+2\kappa(-\beta^3\gamma-4\alpha\beta^3\cos B\\&+4\alpha^2\beta^2\cos A+3\alpha^2\beta\gamma+2\alpha\beta^2\gamma\cos C)+(\alpha^2+2\alpha\beta\cos C+\beta^2)^2\}.\end{aligned}$$

But, if V denote the volume of the tetrahedron constituted by the centre of the sphere and the angular points of the triangle of reference,

$$\begin{aligned}(6V)^2&=\Sigma(a^2\alpha^2+2bc\beta\gamma\cos a)\\&=(a\alpha+b\beta\cos c+c\gamma\cos b)^2+b^2c^2(\beta^2+2\beta\gamma\cos A+\gamma^2).\end{aligned}$$

Hence if $p=0$ be a double focus, its quadrantal polar $(a\alpha+b\beta\cos c-c\gamma\cos b=0)$ is a double cyclic arc (See § 7.)

The proposition seems to be susceptible of simple proof and of generalization.

4. If a spherical curve have a multiple cyclic arc, it has at least a double focus.

Let the triangle of reference be trirectangular (which assumption does not affect the generality of the proof), and let the quartic exhibit AB as a multiple cyclic arc:—

$$\phi_r z^n+(x^2\pm y^2+z^2)\chi_m=0.$$

The terms may be thus grouped.—

$$(x^2+y^2)\chi_m+z^2(z^{n-2}\phi_r+\chi_m).$$

In this form the imaginary lines $(x\pm yi=0)$ are seen to meet AB in two coincident points I, J, the tangents at these points are these arcs CI, CJ. their point of concurrence is therefore a double focus. This proof seems applicable only to the case where the focus is the quadrantal pole of the cyclic arc, the points I, J being in this case the shadows of the circular points at infinity.

The argument may be also thus stated. The two lines

$$(x\pm yi=0)$$

are common tangents to the curve, and to the imaginary sphere $(x^2+y^2+z^2=0)$ at their point of contact of a high order; their intersection is consequently a quadruple, or, if real values alone are considered, a double focus, and might be a multiple focus of a higher order.

5. On equiharmonic or neutral cubics with double foci The cusps are collinear, and in this case S, an invariant of the cubic equation, $=0$

$$(4\cos^2 A-3)\kappa^2+2(\cos A+3\cos B\cos C+2\cos A\cos^2 C)\kappa+\sin^4 C=0.$$

There are two possible or coincident or impossible cases, according to the value of the parameter.

The two values coincide if

$$\sin^4 C(4\cos^2 A-3)=(\cos A+3\cos B\cos C+2\cos A\cos^2 C)^2,$$

or

$$(\cot B+3\cos a\cot C)(\cot B+\cos a\cot C)+3\sin^2 a=0,$$

the biangular equation to a conic.

That is, the locus of the double focus when the cusps are collinear, or the bounding curve, on either side of which equiharmonic values are or are not possible, is a spherical ellipse, whose cyclic arcs, real or imaginary, are perpendicular to the line connecting the single focus and satellite.

In plano the bounding line is thus denoted :—

$$\cot B+3\cot C=0, \text{ or } \cos C=-\frac{a}{2b}$$

The double focus is in a line, which cuts orthogonally the connector of the single focus and the satellite.

6. On harmonic cubics with double foci.

The invariant T=0

$$\cos A\,(9-8\cos^2 A)\kappa^3+\tfrac{3}{2}\{6-4\cos^2 A-9\cos^2 B+3\cos^2 C-8\cos^4 A\cos^2 C$$
$$-12\cos A\cos B\cos C\}\kappa^2+3\sin^2 C\,(\cos A+3\cos B\cos C+2\cos A\cos^2 C)\kappa+\sin^6 C=0.$$

For every position of the foci and satellite there is at least one value of the parameter which yields a harmonic cubic.

7. On the discriminant of the cubic.

Equate α to zero in the point-equation (§ 3), besides the point of contact $(\beta-\kappa\gamma=0)$, three tangential points are determined by the aggregate :—

$$\kappa\gamma(\beta^2+2\beta\gamma\cos A+\gamma^2)-\beta(\beta^2\sin^2 B+2\beta\gamma\sin B\sin C\cos a+\gamma^2\sin^2 C)$$

Since the anharmonic ratio of the lines connecting the tangential points depends upon the function $64-\frac{T^2}{S^3}$, the discriminant of the ternary cubic is simply found from this binary cubic :—

$$\{9\kappa\sin^2 B+(2\kappa\cos A-\sin^2 C)(\kappa-2\sin B\sin C\cos a)\}^2$$
$$+4\{3\sin^2 B(2\kappa\cos A-\sin^2 C)+(\kappa-2\sin B\sin C\cos a)^2\}$$
$$\times\{3\kappa(\kappa-2\sin B\sin C\cos a)-(2\kappa\cos A-\sin^2 C)^2\}=0.$$

8. By dualising, this investigation is equally applicable to order-cubics with double cyclic arcs and double foci.

Résumé of Researches on the Inverse Problems of Moments of Inertia and of Moments of Resistance. *By* Professor Giuseppe Jung (*Milan*).

In the study of the resistance of materials and the stability of constructions, the two following problems continually present themselves :—

I. To construct a plane figure (for example, the cross-section of a cylinder loaded in a given manner) of which we may suppose given the orientation, the form, the centre of gravity, and also the moment of inertia with respect to a given neutral axis.

II. To construct a plane section, given the orientation, the form, the centre of gravity, and also the *moment of resistance** with respect to a given neutral axis

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* If ϵ is an element of a plane section F, and y be the distance of the barycentre of ϵ from an axis x measured in the direction λ (λ being a straight line making any angle with the axis x), then the moment of inertia of F with respect to x in the direction λ is $=\Sigma\epsilon y^2=J$, the Σ extending over the contour of F.

If, besides, v is the distance (measured parallel to λ) of the barycentre O of F from the tangent to F parallel to x and furthest removed from O, then the moment of resistance of F with respect to a barycentric axis x, in the direction λ, is defined to be the ratio $\frac{J}{v}$. In fact, if we multiply this ratio by a certain constant we have the ordinary moment of resistance of the section F.

These two problems have recently engaged my attention.

It is well known that engineers resolve these questions by tentative methods which sometimes require long calculations, and which besides are incapable of performance when the section is quite irregular; and this is why it is necessary to fix types (such as a Zorès iron, T's, I's, &c.) which, being decomposable into parts whose moments of inertia or moments of resistance can be determined analytically, are calculable.

By the simple and uniform graphical method which I have proposed, we can treat in the same manner as the simple sections (triangles, rectangles, &c.) the most complicated forms (such as a Zorès iron or even figures with arbitrary and irregular contours, whose equations would not admit of expression), so that, in order to render possible the solution of these important problems, we need sacrifice nothing, either from the economical or the æsthetic point of view.

I. Let F be the unknown figure that we wish to construct, J its moment of inertia in a direction λ with respect to a given barycentric axis r[*], F' a figure homothetical to F, O' its centre of gravity, and x' a straight line parallel to x and passing through O'.

Let, besides, k be the (unknown) radius of gyration of F, in the direction λ with respect to x, so that $J=k^2F$, and let J' and k' be analogous quantities to J and k, relating to F'.

Finally, let us suppose two orthogonal axes u, w drawn anywhere, on which we have respectively the segments UA = WA = 1, A being the point of intersection of u and w.

Solution. (*a*) We find directly J' the moment of inertia of F', either by the integrometer or graphical (*e.g.* by Culmann's) method.

(*b*) On the axis u take two segments AB, AB' respectively proportional to J and J', and describe two semicircles on the diameters UB, UB' which intercept on the axis of w the segments AC, AC' respectively proportional to $\sqrt{J}$ and $\sqrt{J'}$, and two semicircles upon the diameters WC, WC' which intercept upon u the two segments AD and AD' respectively proportional to $\sqrt[4]{J}$ and $\sqrt[4]{J'}$.

(*c*) From O' draw a straight line x' parallel to x, and take upon x' and x the segments O'X', OX respectively equal or proportional to AD' and AD, so that X is with respect to O on the same side as X' with respect to O'. Draw the straight lines O O' and X X' meeting at the point S.

(*d*) Finally, transform the figure F' into the homothetical figure F, taking S as centre of similitude, that is to say, draw through S a series of lines cutting the contour of F' in the points M', and the corresponding points M of the required contour F are formed by constructing the intersections of the radii SM' with the straight lines OM parallel to O'M'.

This figure F is evidently the section required, that is to say, a figure which has given the centre of gravity, the orientation, the form, and also the moment of inertia, in the direction λ, with respect to x, equal to the given quantity J. In fact the ratio of similitude of the two figures F and F' is $=\sqrt[4]{J}\cdot\sqrt[4]{J'}$.

Note 1. When J' has been found, we can calculate directly the number

$$\sqrt[4]{\left(\frac{J}{J'}\right)}=\mu;$$

and then we should take O'X' upon x' arbitrarily, and on OX we should take $OX=\mu.O'X'$; we should then continue the procedure as above.

Note 2. If the position of x and the magnitude of J are not given absolutely, *i. e.* if the inverse problem is to be resolved several times supposing x and J successively variable, and if for the determination of J' (see (*a*)) we employ the graphical method, it is convenient to use the central ellipse of F'.

On this point, and for more details, see three notes that I have published in vol. ix. of the 'Rendiconti dell' Istituto Lombardo,' 1870, or my memoir, "Sul problema inverso dei momenti d'Inerzia" in vol. xxiv. of the 'Politecnico, Giornale dell' Ingegnere architetto civile ed industriale' (Milano, 1876), which contains two lithographic tables, and, as an appendix, a comparison between the numerical and the graphical calculation of a Zorès iron.

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[*] We may restrict ourselves to consider the axes which pass through the centre of gravity O of F, on account of the well-known relation between the moments of inertia which have reference to these axes, and those which have reference to any parallel axes.

II. Retaining the same notation as before, let R be the given moment of resistance of F in the direction λ with respect to a given barycentric axis x, *i.e.* let $R = \frac{J}{v} = F \cdot r$, where $r = \frac{\lambda^2}{v}$ is the radius (or arm) of resistance of F with respect to x in the direction λ.

Let R' and r' be analogous quantities to R and r for the figure F'.

Solution. Find directly R' (for example, by Culmann's graphical method), determine, either graphically or by a numerical calculation, the ratio

$$\sqrt[3]{\frac{R}{R'}} = \mu,$$

draw through O' a straight line x' parallel to x, take on x' any segment O'X' and on x a segment $OX = \mu$ O'X' so that X is with respect to O on the same side as X' with respect to O'; and draw the straight lines OO' and XX cutting one another in S.

Then transform the figure F' into the homothetical figure F, taking S as centre of similitude (see above). This figure F is evidently the required section, that is to say, a figure which has the given barycentre, orientation, and form, and also the moment of resistance in the direction λ with respect to the axis x = the given moment R.

For further details see the notes already cited in the 'Rendiconti dell' Istituto Lombardo,' 1876, and also the memoir "Sul problema inverso dei momenti di resistenza,' which will appear in the 'Politecnico, Giornale dell' Ingegnere arch. civ. ed industr.' (Milano, 1876).

Résumé of Researches upon the Graphical Representation of the Moments of Resistance of Plane Figures. By Professor GIUSEPPE JUNG (*Milan*).

Continuing the investigation upon the moments of resistance of a given plane figure F, I have communicated to the Istituto Lombardo [*] some results which I have obtained, and of which I here give a short account.

1. Retaining the same notation as in the last paper, I have given several graphical methods for calculating the radii of resistance r in an arbitrary direction λ (and, consequently, the corresponding moments of inertia $R = F \cdot r$) of the figure F with regard to any barycentric axis x, and I have found several *representative curves*, viz. in this sense that these curves have for radii vectores the radii of resistance r. So that, having given an axis x and one of the representative curves (which I show how to construct), we have the corresponding moment of resistance by multiplying by the area F of the section a certain radius vector of the representative curve.

It is remarkable that when the direction λ is conjugate to the direction of the given axis x (*i e.* that when the diameter of the central ellipse of F parallel to λ is conjugate to the diameter x), one of the representative curves is the central nucleus (Centralkern) [†] of the figure F, and we have the following theorem:—

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[*] See 'Rendiconti dell' Istituto Lombardo,' ser 2, t. ix 1876, No xv. "Rappresentazioni grafiche dei momenti resistenti di una sezione piana." No xvi "Complemento alla nota precedente."

[†] Perhaps it will be useful to recall here rapidly some notions which are, however, well known (see, for example, my memoir "Sui momenti d'Inerzia" in the 'Rendiconti dell' Istituto Lombardo,' 1875).

In the plane of F to every straight line, considered as a neutral axis, corresponds a point X which is the centre of the pressures (tensions) or the centre of the second degree or the point of application of the resultant of the normal forces acting on the section F. This point X is also called the antipole of the straight line x, and the straight line x is the

The radius of resistance with respect to a barycentric axis, in the direction of the conjugate diameter, is equal to the smaller of the two radii vectores of the central nucleus situated on the latter diameter.

We thus see that the central nucleus stands in nearly the same relation to the radii of resistance that the central ellipse does to the radii of gyration of the figure F. In fact the difference consists chiefly in this, that each of the radii vectores of the ellipse situated on the diameter y is equal to the radius of gyration of F with regard to the conjugate diameter x, while in general one only (the smaller) of the two radii vectores of the nucleus situated upon y is equal to the radius of resistance of F with regard to the conjugate diameter x.

2. Suppose that F is a cross-section of a cylinder upon which are acting forces situated in a plane passing through its axis, the intersection of this plane with the plane of F is the *axis of sollicitation* of the section F, and the straight line which passes through its barycentre and is conjugate to the axis of sollicitation is the neutral barycentric axis. This being premised, I show that

The moment of resistance with respect to a barycentric axis x, *in the conjugate direction* y, *is equal to the resistance specific** *to the cohesion with respect to the flexure relatively to the axis of sollicitation* y.

From which follows a theorem giving the law of variation of the specific resistance of F, when the axis of sollicitation turns round its centre of gravity, viz. —

The central nucleus of a given section is the curve of resistances specific to the cohesion with respect to the flexure. A radius of the nucleus (the smaller of the two situated on the barycentric axis considered) multiplied by the area F *gives the specific resistance with respect to its direction, considered as axis of sollicitation.*

3. Taking still the barycentre of F as pole and for radii vectores segments proportional to the maxima† specific resistances of the section with respect to the flexure and corresponding to each axis of sollicitation, I find the remarkable theorem:—

The curve of maxima resistances of F *is a transformation by reciprocal radii vectores (the inverse*‡*) of the central nucleus of the section. A radius vector of this inverse curve, multiplied by* $\frac{1}{F}$, *gives the specific maximum resistance of* F *with respect to its direction, considered as axis of sollicitation.*

4. Two other theorems are connected with a note of M. Ritter, "Ueber eine neue Festigkeitsformel" (see the 'Civilingenieur,' 1876, Heft iii., iv.). The more important is that which gives a simple solution of the following question:—Given the point of application of the resultant of the forces which act normally on the section F and also the central nucleus, but not the central ellipse, of F, find the neutral axis corresponding to this point.

If O is the centre of gravity of F, C the point of application (in the plane of F)

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antipolar of the point X. If in any one given direction λ, d is the distance of the centre of gravity of F from the straight line x, and k is the radius of gyration of F with respect to the barycentric axis parallel to x, the distance, measured parallel to λ, of the straight line x from its antipole $= d + \frac{k^2}{d}$. If a straight line y passes through X, its antipole y lies upon x. The point X, which is the antipole of the straight line x in this reciprocal system (antipolar system), is also the pole, in Poncelot's sense, with respect to the central ellipse of F, of the straight line x' which is symmetrical to x with respect to the point O (barycentre of F and centre of its central ellipse).

If a variable straight line envelops the contour of F without cutting it, its antipole X describes a closed curve which is the central nucleus (Centralkern) of the figure F (see Culmann, 'Die graphische Statik,' 2nd edition, t. i. 3ter Abschnitt, Zurich, 1875).

* It is the moment of resistance of the section for which, the axis of sollicitation of the forces being given, the unit of tension (or of pressure) is produced in the most distant fibre of the neutral axis upon the unit of area of this fibre.

† That is, the maximum unit tensions (or pressure) on the hypothesis that the moment of the exterior forces which produces the flexure in the sections of the cylinder is $=1$.

‡ See, for example, Hirst, "Inversione quadratica" ('Annali di Matematica,' Roma, 1st series); Darboux, 'Sur une classe remarquable de courbes et de surfaces algébriques,' Paris, 1873.

of the resultant of the forces which act normally upon F, C′ the point in which OC is met by the (unknown) neutral axis, A and B the points in which OC meets the contour of the central nucleus, A′ and B′ the points in which OC meets respectively the antipolars of A and B *, then this last theorem can be enunciated thus.

The point C′ is conjugate to C in the involution AA′, BB′.

Consequently, if C is given, we have C′ linearly, and we construct the neutral axis by drawing through C′ a straight line parallel to the conjugate direction of OC.

On a new Construction for the Central Nucleus of a Plane Section

By Professor GIUSEPPE JUNG (*Milan*).

I have the honour to communicate to Section A a new and very easy method of representing the radii of gyration of a given plane (figure F), which appears to be more simple than the known methods of Poinsot, Reye, and Mohr.

From this representation I deduce a new construction for the central nucleus of F, independent of that of the central ellipse of the figure. This I regard as interesting, because of the importance of the central nucleus in the study of the stability of constructions, on account of its remarkable properties with regard to the moment of resistance of the section &c. (See Culmann, 'Die graphische Statik,' and the memoirs of which a *résumé* has just been given.)

1. Let O be the centre of gravity of F, AA and BB its principle axes of inertia, *i. e.* the axes of the central ellipse E of F, f and f' (upon AA) the two foci of E, C the circle which has for diameter the major axis AA. Then *the radius of gyration of F (in the normal direction), with respect to any barycentric axis x, is the segment MM′ of the perpendicular drawn to x from one of the points $f f'$ included between the axis x and the circle C.* In fact the circle C is the locus of the feet of the perpendiculars let fall from the foci $f f'$ upon the tangents to the ellipse E.

Thus the circle C represents the radii of gyration of F (in the normal direction) with respect to all the barycentric axes. If from M we draw the straight line m parallel to x, the segment NN′ of any straight line λ, included between x and m, is equal to the radius of gyration with respect to x in the arbitrary direction λ, that is to say, if we take the angle $\lambda x = 90 - \omega$, we have the radius of gyration, in the direction λ, $= \dfrac{MM'}{\cos\omega} = NN'$. We can dispense with the perpendiculars. It is sufficient to construct, besides the circle C, the circle Γ on Of as diameter: if x meets the circle Γ in the point M, and Mf be drawn cutting the circle C in the point M′, the segment MM′ will be the required radius of gyration.

2. Let G be a circle passing through O, and of arbitrary radius †. If through the points A we draw two parallels to BB, and through the points B two parallels to AA, the diagonals of the rectangle so produced meet G in two points a and a', and the straight lines AA, BB meet the same circle in β and β'. Let U be the point of intersection of the chords $a a'$ and $\beta \beta'$.

By means of this point U we construct the barycentric axis y, conjugate to any given barycentric axis x. It is only necessary to observe that if x cuts G in the point X, and XU cuts G in the point Y, the straight line OU is the axis y required. This is, in fact, merely the construction for the radius y conjugate to x in the involution of the straight lines O(A B. $a a'$); but these latter are two pairs of conjugate diameters of the central ellipse of F, whence &c.

3. Construction for the central nucleus. Draw any suitable number of straight lines enveloping the contour of F without cutting it. Let l be one of these lines, *i. e.* a tangent which does not cut elsewhere the contour of F (unless it be convex). Draw through O the axis x parallel to l, and through f the perpendicular to l, which meets l, x, and the circle C in the points V, M, and M′ respectively. With centre M and radius MM′ describe a circle, intercepting on x the distance MK′

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* These antipolars are tangents to the contour of F and parallel to the conjugate direction of OC; and we know that the barycentre O is situated on each of the finite segments AA′ and BB′.

† We might take G coincident with Γ; then β coincides with f and β' with O, and U is the point of intersection of aa' and AA′.

(=radius of gyration, normal with respect to x; see No. 1), and through K′ draw the perpendicular to K′V meeting MM′ in the point K. The straight line passing through K and parallel to l cuts the axis y, conjugate to x (see the construction for it in No 2), in the point L, antipole of l[*]; consequently L is a point on the central nucleus.

Centroids, and their Application to some Mechanical Problems. *By* Professor A. B. W Kennedy

Elementary Demonstration of a Fundamental Principle of the Theory of Functions. *By* Paul Mansion, *Professor in the University of Ghent.*

M. Thomae ('Abriss einer Theorie der complexen Functionen,' 2te Auflage, Halle, 1873, pp 11–13) first demonstrated rigorously the theorem that "a function $y=\mathrm{F}x$, whose differential coefficient, both in the positive and in the negative direction, is zero for every value of x, from x_0 to X, is constant in this interval." This important proposition can be demonstrated in an elementary manner by the following method, which seems capable also of other applications

I. If the differential coefficient of a function $y=\mathrm{F}x$ in the positive direction is the same as in the negative direction, this differential coefficient is equal, for a system of values (x, y), to the limit of the ratio $\frac{\mathrm{F}(x_2)-\mathrm{F}(x_1)}{x_2-x_1}$, x_2 and x_1 converging towards the *intermediate value x*.

In fact, by hypothesis,

$$\mathrm{F}x_2-\mathrm{F}x=(x_2-x)(y'+\epsilon_2),$$
$$\mathrm{F}x_1-\mathrm{F}x=(x_1-x)(y+\epsilon_1),$$

ϵ_1 and ϵ_2 being infinitely small. Consequently

$$\frac{\mathrm{F}x_2-\mathrm{F}x_1}{x_2-x_1}=y'+\epsilon_1\frac{x_1-x}{x_1-x_2}+\epsilon_2\frac{x_2-x}{x_2-x_1},$$

and, ϵ_1 and ϵ_2 being multiplied by proper fractions, since x is intermediate to x_1 and x_2,

$$\lim\frac{\mathrm{F}x_2-\mathrm{F}x_1}{x_2-x_1}=y'.$$

II. Let $x_0, x_1, \ldots. x_{n-1}$, X be increasing values of x, to which correspond the values $y_0, y_1, \ldots\ y_{n-1}$, Y of the function $y=\mathrm{F}x$.

We have

$$\frac{\mathrm{Y}-y_0}{\mathrm{X}-x_0}=\frac{(y_1-y_0)+(y_2-y_1)\ \ldots(\mathrm{Y}-y_{n-1})}{(x_1-x_0)+(x_2-x_1)\ .\ \ (\mathrm{X}-x_{n-1})}.$$

It results from this equation that $\frac{\mathrm{Y}-y_0}{\mathrm{X}-x_0}$ has a value intermediate to the greatest and least of the ratios $\frac{y_i-y_{i-1}}{x_i-y_{i-1}}$, unless they are all equal. Thus.—*Unless all the* $\frac{\Delta y}{\Delta x}$*'s are equal in the interval* (x_0, X), *there is at least one of them greater than and one of them less than* $\frac{\mathrm{Y}-y_0}{\mathrm{X}-x_0}$.

III. *If the differential coefficients of a function* $y=\mathrm{F}x$ *are the same in the positive direction as in the negative direction, from* x_0 *to* X, *then either all these differential*

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[*] In fact if OL$=y$ meets l in L′, and if k is the radius of gyration with respect to x in the conjugate direction y, we have, by construction, $\mathrm{L'L}=\mathrm{L'O}+\frac{k^2}{\mathrm{L'O}}$, but the distance, in the direction y, of the straight line l from its antipole has exactly this value (see note to my '*Résumé* of Researches upon the Graphical Representation' &c), therefore L is the antipole of l.

coefficients are equal, or there is at least one of them greater than and one less than $\frac{Y-y_0}{X-x_0}$.

Subdivide the interval $X-x_0$ into n parts: the $\frac{\Delta y}{\Delta x}$ corresponding to one of them, x_i-x_{i-1}, will be greater than $\frac{Y-y_0}{X-x_0}$ (No. II.). Operate in the same manner with x_i-x_{i-1}, and so on. We shall thus have an indefinitely increasing series of $\frac{\Delta y}{\Delta x}$'s, all greater than $\frac{Y-y_0}{X-x_0}$ (No. II.), and having for limit the differential coefficient y' of Fx for a certain value of x (No. I.). There is, then, a differential coefficient y' greater than $\frac{Y-y_0}{X-x_0}$. In the same way we can show that there is one smaller. We must, however, except the case of $\frac{\Delta y}{\Delta x}$ constant, which arises when $y=ax+b$.

IV. *If the differential coefficient of a function, supposed the same in the positive and negative directions, is equal to a constant a, from x_0 to X, the function is linear and of the form $ax+b$.*

Necessarily, x and x_1 being any two values included in the interval (x_0, X),

$$\frac{y-y_1}{x-x_1}=a,$$

whatever x and x_1 may be. For, were it otherwise, there would be between x and x_1 a differential coefficient greater than a, and one smaller than a. Thus:—

$$y=ax+(y_1-ax_1)$$

Corollary.—If $a=0$, $y=$constant. Q.E.D.

On Convergents. By Thomas Muir, *M.A., F.R.S.E.*

In Lagrange's additions to Euler's Algebra (2nd Eng. ed. vol. ii. p. 279), he sets himself the problem,—*A fraction expressed by a great number of figures being given, to find all the fractions, in less terms, which approach so near the truth that it is impossible to approach nearer without employing greater ones*, and for solution he gives in effect the following rule:—*Transform the given fraction into a continued fraction with unit numerators and positive integral partial denominators, and the so-called convergents of this continued fraction will be the fractions required.* In this he is in error, the fractions found being *some* of the fractions required, but not *all*. Thus, taking π as the given fractional form, he transforms it into

$$3+\frac{1}{7+}\,\frac{1}{15+}\,\frac{1}{1+}\ldots$$

the so-called convergents of which are $\frac{3}{1}, \frac{22}{7}, \frac{333}{106}, \frac{355}{113}, \ldots$, and in regard to them he says:—"So that we may be assured that the fraction $\frac{3}{1}$ approaches nearer the truth than any other fraction whose denominator is less than 7, also the fraction $\frac{22}{7}$ approaches nearer the truth than any other fraction whose denominator is less than 106; and so of others."

The statement here made in reference to $\frac{3}{1}$ is easily seen to be incorrect by comparing the difference of $\frac{3}{1}$ from π with that of $\frac{13}{4}, \frac{16}{5}$, or $\frac{19}{6}$, the former being, of course, ·14159 . . . , and the three latter ·10840 . . . , ·05840 . . . , ·02507 . . . ; and the incorrectness extends to what is said of the other convergents. The true solution lies in the fact that not only is $3+\frac{1}{7}$ one of the required fractions, but so also are $3+\frac{1}{4}$, $3+\frac{1}{5}$, $3+\frac{1}{6}$, where the denominator we begin with is *the first integer greater than the half of 7*; similarly, that before we come to

$$3+\frac{1}{7+}\frac{1}{15}$$

we have

$$3+\frac{1}{7+}\frac{1}{8},$$

$$3+\frac{1}{7+}\frac{1}{9},$$

$$3+\frac{1}{7+}\frac{1}{10}$$

and so on. When an *even* partial denominator occurs, we take as the partial denominator to begin with, either its half or the first integer greater than its half, according as the partial denominator following is greater or less than that preceding, or these being equal, according as the next following is less or greater than the next preceding, and so on.

Another improvement, though verbal, is important, viz. in regard to the term *convergent*, the present definition of which seems arbitrary and unreasonable. With great convenience it may be defined as follows:—*A convergent of a fractional number is a fraction which is a closer approximation to the given number than any other fraction with a smaller denominator*; so that Lagrange's problem is simply *to find all the convergents of any fraction*.

On the Relation between two continued Fraction Expansions for Series.
By THOMAS MUIR, *M.A., F.R.S.E.*

On the Use of Legendre's Scale for Calculating the First Elliptic Integral.
By Professor F. W. NEWMAN.

Denoting the first elliptic integral by $F(c,\omega)$ and taking x such that $x\cdot\frac{1}{2}\pi = F(c,\omega) \div F(c,\frac{1}{2}\pi)$, then, in Lagrange's scale, from ω we deduce successively ω_1, ω_2, ω_3 ... by a given law, with the aid of c_1, c_2, c_3 ... previously determined from c. Then x is the limit to which ω, $2^{-1}\omega_1$, $2^{-2}\omega_2$, $2^{-3}\omega_3$ ... converge. If c is moderately small, the convergence is rapid. But if c^2 is very near to 1, it may be expedient to reverse the direction of the new amplitudes and moduli, viz. to calculate backwards c, c, c ... so as to make c, c, c, c, c_1, c_2 ... a series continued by a single law, and similarly from ω calculate backwards ω, ω, ω ... Then ω, ω, ω ... are proved to converge to a fixed limit ω and $F(c, \omega) \div F(b, \frac{1}{2}\pi) =$ Nap log tan $(\frac{1}{4}\pi+\frac{1}{2}\omega) \div \frac{1}{2}\pi$. The function Nap log tan $(\frac{1}{4}\pi+\frac{1}{2}\omega)$ involves but a single element ω, and was calculated by Legendre. Gudermann has since published a far ampler table. In practice the limit ω is quickly reached; often it suffices to make $\omega=\omega$, at worst $\omega=\omega$. Thus for very large values of c^2 Lagrange's scale practically suffices, presuming that we have at hand tables of $F(c, \frac{1}{2}\pi)$ and $F(b, \frac{1}{2}\pi)$.

But Legendre, who discovered a new scale after completing his principal calculations, regarded his new scale as having much advantage in finding $F(c, \omega)$ at once rapidly and accurately. In it x is the limit of ω, $3^{-1}\omega_1$, $3^{-2}\omega_2$, $3^{-3}\omega_3$ ..., and the convergence, generally excellent in Lagrange's scale, is far more rapid in Legendre's. In Lagrange's scale the relation of ω_1 to ω is $\tan(\omega_1-\omega)=b\tan\omega$. The relation in Legendre's scale is to the eye as simple, viz. $\tan\frac{1}{2}(\omega_1-\omega)=A\tan\omega$, but in the constant A, $=\sqrt{(1-c^2\sin^2\beta)}$, the value of β is determined by the equation $F(c, \beta)=\frac{1}{3}F(c, \frac{1}{2}\pi)$. A practical difficulty arose in the very considerable trouble needed to obtain A (or its logarithm) numerically when c was given. Legendre showed how β was obtainable from c; the cubic equation arising can be solved by a mere extraction of the cube-root, but there are also two quadratics involving two extractions of the square-root. Then from β we have to calculate $\sqrt{(1-c^2\sin^2\beta)}$

and find its logarithm before we can proceed to deduce ω_1 from ω. All these operations have to be repeated to find ω_2 from ω_1, nay, we must first find c_1 from c, and that is still more arduous.

But when we assume $\rho, =\frac{1}{2}\pi\frac{F(b, \frac{1}{2}\pi)}{F(c, \frac{1}{2}\pi)}$, as argument, all is greatly simplified. The relation of c, c_1, c_2, c_3 … in Lagrange's scale corresponds with $\rho, 2\rho, 2^2\rho, 2^3\rho$, …, and in Legendre's scale with $\rho, 3\rho, 3^2\rho, 3^3\rho$ …, which involve no trouble in calculating. No doubt we need tables (of single entry and easily compiled) to yield c, b when ρ is given, and ρ when c is given. Presuming these, we may treat c and $F(c, \omega)$ as functions of ρ and ω, after which the difficulties of the constant multiplier A vanish, and Legendre's scale becomes practical to us.

Denote $-\log A$, i.e. $-\log\sqrt{(1-c^2\sin^2\beta)}$, for the moment, by $\Phi(\rho)$ (here the common log is intended), then, among the numerous series which express functions of the amplitude ω in terms of x and ρ, the author selects (with λ for Napier's log)

$$-\tfrac{1}{2}\lambda\sqrt{(1-c^2\sin^2\omega)}=\frac{1-\cos 2x}{\sin 2\rho}+\frac{1}{3}\frac{1-\cos 6x}{\sin 6\rho}+\frac{1}{5}\frac{1-\cos 10x}{\sin 10\rho}+\&c.$$

where $\sin\rho$ is written for $\frac{1}{2}(e^{\rho}-e^{-\rho})$. By hypothesis, $F(c, \beta)=\frac{1}{3}F(c, \frac{1}{2}\pi)$, hence when $\omega=\beta$, $x=\frac{1}{6}\pi$, and we get, writing $\text{cosec}\,\rho$ for the reciprocal of $\sin\rho$, $\frac{1}{2}\Phi(\rho)$ $=M\{\text{cosec}\,2\rho+\frac{1}{5}\,\text{cosec}\,10\rho+\frac{1}{7}\,\text{cosec}\,14\rho+\frac{1}{11}\,\text{cosec}\,22\rho+\&c.\}$, M being the modulus of the common logarithms.

Assuming that we have a table of $\Phi(\rho)$, then given ρ and ω we have the equation $\log\tan\frac{1}{2}(\omega_1-\omega)=\log\tan\omega-\Phi(\rho)$ to find ω_1, $\log\tan\frac{1}{2}(\omega_2-\omega_1)=\log\tan\omega_1-\Phi(3\rho)$ to find ω_2, $\log\tan\frac{1}{2}(\omega_3-\omega_2)=\log\tan\omega_2-\Phi(3^2\rho)$ to find ω_3, and so on. The approximation is sufficient when $\Phi(3^n\rho)$ is negligible, and this result is obtained so rapidly, that in the extreme case of $\rho=\frac{1}{2}$, $x=3^{-2}\omega$, is correct to ten decimals.

To bring the method to a practical trial the author has calculated to twelve decimals a skeleton table of $\Phi(\rho)$ for $\rho=0{\cdot}5$, $0{\cdot}6$, $0{\cdot}7$, $0{\cdot}8$, $0{\cdot}9$, and from $\rho=1$ to $\rho=14{\cdot}3$ at intervals of $0{\cdot}1$. The table is given in the paper, and also examples of the method. The process also by which the table was constructed, with the aid of tables of $\text{cosec}\,\rho$ and $e^{-\rho}$, previously calculated by the author, is explained.

General Theorems relating to Closed Curves. *By* Professor P. G. TAIT.

The closed curves contemplated are supposed to have nothing higher than double points. By infinitesimal changes of position of the branches intersecting in it, a triple point is decomposed into three double points, a quadruple point into six, and generally an $x$ple point into $\frac{x(x-1)}{1\cdot 2}$ double points. (1) A closed curve cuts any infinite unknotted line in an even number of points [infinite here implies merely that both ends are outside the closed curve]. (2) The same is true if the line be knotted. (3) If any two closed curves cut one another, there is an even number of points of intersection. (4) In going continuously along a closed curve from a point of intersection to the same point again an even number of intersections is passed. (5) Hence in going round such a closed curve we may go alternately above and below the branches as we meet them. (6) By (3) the same proposition is true of a complex arrangement of any number of separate closed curves superposed in any manner. (7) In passing from the interior of any one cell to that of any other—in any system of superposed closed curves—the number of crossings is always even or always odd, whatever path we take. (8) Hence the cells may be coloured black and white in such a way that from white to white there is always an even number of crossings, and from white to black an odd number. Such closed curves therefore divide the plane as nodal lines do a vibrating plate.

The above are the enunciations of the propositions proved in the paper, which, with the necessary figures &c., will be found printed *in extenso* in the 'Messenger of Mathematics,' vol. vi., January 1877.

On a Theorem in the Mensuration of certain Solids.
By Professor JAMES THOMSON.

On Division-remainders in Arithmetic. *By* W. H. WALENN.

The author referred to a series of papers of his on unitation recently published in the 'Philosophical Magazine,' and to some remarks published in the Brit. Assoc. volume for 1870. If x divided by δ leave remainder y, then the author calls y the unitate of x to the base δ, and writes $U_\delta x=y$. The results of "unitation" may be conveniently applied to the verification of many numerical operations. The method of unitation is practically equivalent to the theory of congruencies, viz. the equation $U_\delta x=y$ would be written $x \equiv y \pmod{\delta}$, and many of the results are identical with those given by Gauss.

On Many-valued Functions. *By* M. M. U. WILKINSON, *M.A.*

GENERAL PHYSICS, &c.

On the Transformation of Gravity. *By* JAMES CROLL, *F.R.S.*[*]

On the Influence of the Residual Gas on the Movement of the Radiometer.
By WILLIAM CROOKES, *F.R.S.*

The author's recent experiments show that the movement of this instrument is not due to a direct repulsion exerted by light on the vanes, but to a mutual action called out between these vanes and the very attenuated gas remaining in the instrument. It is well known that, with a moderately good vacuum, the motion becomes more rapid as the exhaustion proceeds, but he has recently succeeded in producing such a complete exhaustion that he not only reaches the point of maximum effect, but goes so far beyond it that the effect nearly ceases. The vacuum is measured by means of a special apparatus, in which a moving plate, instead of continuously rotating in one direction, as in the ordinary radiometer, is suspended by a glass fibre, which it twists in opposite directions alternately. The movement is started by rotating the whole apparatus through a small angle, and the observation consists in noting the successive amplitudes of vibration when the instrument is left to itself, a mirror and spot of light being employed for this purpose. The amplitudes form a decreasing series, with a regular logarithmic decrement. The logarithmic decrement is nearly constant up to the point at which the vacuum is apparently equal to a Torricellian vacuum, the mercury in the gauge standing at the same height as a barometric column beside it; but as the exhaustion proceeds beyond this point, the logarithmic decrement becomes smaller—in other words, the amplitude diminishes less rapidly. By plotting the observations and supposing the curve continued, it is indicated that, if a perfect vacuum were attained, and the glass fibre had no viscosity, the logarithmic decrement would be zero, we should have perpetual motion with constant amplitude, whilst, at the same time, the radiometer would cease to act. Other gases as well as air have been tried. Aqueous vapour is very unfavourable to the action of the radiometer; hydrogen, on the contrary, gives the best result of all. Several experiments have been already described, which seem to point to the true explanation of the action of the radiometer; but the author thinks Mr. Stoney's explanation the clearest. According to this, the repulsion is due to the internal movements of the molecules of the residual gas. When the mean length of path between successive collisions of the molecules is small compared with the dimensions of the vessel, the molecules, rebounding from the heated surface, and therefore moving with an extra velocity, help to keep back the more slowly moving molecules which are advancing towards the heated surface; it thus happens that though the individual kicks against the heated surface are increased in strength in consequence of the heating, yet the number of molecules struck is diminished in the same proportion, so that there is equilibrium on the two sides of the disk, even though the temperatures of the faces are unequal But when the exhaustion is carried to so high a point that the molecules are sufficiently few, and the mean length of path between their successive collisions is comparable with the dimensions of the vessel, the swiftly moving, rebounding molecules spend their force, in part or in whole, on the sides of the vessel, and the onward crowding, more slowly moving molecules are not kept back as before, so that the number which strike the warmer face approaches to, and in the limit equals, the number which strike the back, cooler face, and as the individual impacts are stronger on the warmer than on the cooler face, pressure is produced, causing the warmer face to retreat*

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[*] Printed *in extenso* in the Phil. Mag. 1876, ii. p. 241.

Mechanical Theory of the Soaring of Birds. *By* W. Froude, *F.R S.*

On the Passage of Fluids through Capillary and other Tubes. *By* Professor F. Guthrie *and* Dr. F. Guthrie.

On the Modification of the Motion of Waves produced by Fluid Friction. *By* Prof. J. Purser.

On the Forces experienced by a Lamina immersed obliquely in a Fluid Stream. *By* Lord Rayleigh, *F.R S.*†

On the Resistance encountered by Vortex Rings, and the Relation between the Vortex Ring and Stream-lines of a Disk. *By* Prof Osborne Reynolds.

Description of the Bathometer. *By* Dr. C. W. Siemens, *F.R S.*

On the Amplitude of Waves of Light and Heat. *By* G. Johnstone Stoney, *F.R S.*

On Acoustic Analogues to Motions in the Molecules of Gases. *By* G. Johnstone Stoney, *F.R.S*

Experimental Illustration of the Origin of Windings of Rivers in Alluvial Plains. *By* Professor James Thomson, *LL.D., D.Sc.*

The author referred to a communication which he had made to the Royal Society in the month of May last ‡, in which he had given a new theory of the flow of water round bends in rivers and round bends in pipes, and had explained the reason why, in alluvial plains, the bends of rivers go on increasing by the wearing away of the outer bank, and the deposition of mud, sand, and gravel on the inner bank. The theoretical view which he had then offered, he now, for the first time, had verified by practical experiment; and this experiment he showed in the meeting. The chief point of the new view now experimentally proved was that the water in turning the bend exerts centrifugal force, but that a thin lamina of the water at bottom, or in close proximity to the bed of the river, is retarded by friction with the river-bed, and so exerts less centrifugal force than do like portions of the great body of the water flowing over it in less close proximity to the river-bed. Consequently the bottom layer flows inward obliquely across the channel towards the inner bank, and rises up in its retarded condition between the inner bank and the rapidly flowing water, and protects the inner bank from the scour, and brings with it sand and other detritus from the bottom, which it deposits along the inner bank. The apparatus showed a small river, about 8 inches wide and an inch or two deep, flowing round a bend, and exhibiting very completely the phenomena which had been anticipated.

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* For further researches on this subject, see papers read before the Royal Society, November 16, 1876, and on April 26, 1877.

† Printed *in extenso* in the Phil. Mag. 1876, ii. p. 430

‡ Proc. Roy. Soc. vol. xxv. p 5.

On Metric Units of Force, Energy, and Power, larger than those on the Centimetre-Gram-Second System. By James Thomson, *LL.D., D.Sc., F.R.S.E., Professor of Civil Engineering and Mechanics in the University of Glasgow.*

The author premises that under the excellent method of Gauss for establishing units of force, a unit of force is taken as being the force which, if applied to a unit of mass for a unit of time, will impart to it a unit of velocity. In the system already adopted by the British Association Committee on Dynamical and Electrical Units (Brit. Assoc. Report, part i. 1873, page 222), the Centimetre, the Gram *, and the Second were taken as the units of length, of mass, and of time, and the unit of force thence derived under the method of Gauss was called the *Dyne*.

That force is very small, quite too small for convenient use in all ordinary mechanical or engineering investigations. It is about equal to the gravity of a milligram mass, and that force is so small that it cannot be felt when applied to the hand. That system, designated as the Centimetre-Gram-Second System, recommended by the Committee of the British Association, and described fully, with many applications, in a book since published by Dr. Everett, who was Secretary to the Committee, is well suited for many dynamical and electrical purposes, and it ought certainly to be maintained for use in all cases in which it is convenient. But the object of the present paper is to recommend the employment also of two other systems which are in perfect harmony with it, and to propose names for the units of force under these two systems.

In one of these systems, the Decimetre, the Kilogram, and the Second are the units adopted for length, mass, and time; and thus the system comes to be called the Decimetre-Kilogram-Second System.

In the other, the Metre, the Tonne †, and the Second are adopted as the units of length, mass, and time, and thus the system comes to be called the Metre-Tonne-Second System.

It is to be particularly observed that all the three systems here referred to are framed so as to attain the condition, very important for convenience, that the unit of mass adopted is the mass of a unit volume of water, and that, therefore, for every substance the specific gravity and the density, or mass per unit of volume, are made to be numerically the same.

In the Decimetre-Kilogram-Second System, the unit of force derived by the method of Gauss is 10,000 Dynes, or is about equal to the gravity of 10 Grams. It is impossible, or almost so, to work practically with any such system without having a name for the unit of force. The unit of force in this system is such that a human hair is well suited for bearing it as a pull, with ample allowance of extra strength for safety against breakage; and the author proposes to call it the *Crinal*, from the Latin *crinis* and *crinalis*.

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* The spelling Gram, instead of Gramme, for the English word is adopted in the present paper in accordance with the spelling put forward in the Metric Weights and Measures Act, 1864, which legalizes the use of the Metric System in Great Britain and Ireland.

† The Tonne is the mass or quantity of matter contained in a cubic metre of water, and is nearly the same as the British Ton.

In the Metre-Tonne-Second System the unit of force, likewise derived by the Gaussian method, is 10,000 Crinals, or 100,000,000 Dynes, or is about equal to the gravity of 2 cwt., or of $\frac{1}{10}$ of a ton. This force would be properly borne as a pull by a moderately-sized rope, and the author proposes to call it the *Funal*, from the Latin *funis* and *funalis*.

Then we have One Horse-Power, of 33,000 foot-pounds per minute, about equal to 75,000 Decimetre-Crinals per second, and the Horse-Power is also about equal to ·75 of a Metre-Funal per second.

Also 1 Metre-Funal = 100,000 Decimetre-Crinals,
= 10,000,000,000 Centimetre-Dynes, or Ergs,
= 10^{10} Ergs.

Also 1 Horse-Power is about = 7,500,000,000 Centimetre-Dynes per second,
or as the same may be written 75×10^8 Centimetre-Dynes per second.

The number 7,500,000,000, for expressing a Horse-Power under the Centimetre-Gram-Second System, is an exceedingly unmanageable one, and it gives a very decisive indication that the Centimetre and Gram are too small to be suitable as fundamental units of length and of mass for ordinary engineering purposes, and that there is great need for the establishment of systems having larger units, such as those which have been recommended in the present paper, and for which a convenient nomenclature has been offered.

It is to be observed that the provision made by the British Association Committee, in the Report already referred to, of a multiple of the Dyne, such as the Megadyne, or million of Dynes, as a larger unit of force, does not accomplish all that is to be desired, because various important formulas, or convenient methods of statement, will not hold good when any of the units are so derived. Thus, for instance, if the Megadyne be the unit of force, while the Gram and Second are the units of mass and time, the ordinary formulas for giving the so-called "centrifugal force" of a revolving mass,

$$F = \frac{mv^2}{r} \text{ and } F = m\omega^2 r,$$

will not hold good, and, as another instance, we may notice that the proposition that, in respect to a jet of water, the reaction force on the vessel is equal numerically to the momentum generated per second, will not hold good, and numberless other instances might readily be cited, but those given may suffice.

On the Precessional Motion of a Liquid. By Sir W. Thomson, *D.C.L.*, *F.R.S.*

The formulas expressing this motion were briefly explained, but the analytical treatment of them was reserved for a paper "On the Nutation of a Solid Shell containing Liquid." The chief object of the present communication was to illustrate experimentally a conclusion from this theory which has been announced by the author in his opening address to the Section, to the effect that, if the period of the precession of an oblate spheroidal rigid shell full of liquid is a much greater multiple of the rotational period of the liquid than any diameter of the spheroid is of the difference between the greatest and least diameters, the precessional effect of a given couple acting on the shell is approximately the same as if the whole were a solid rotating with the same rotational velocity. The experiment consisted in showing a liquid gyrostat, in which an oblate spheroid of thin sheet-copper filled with water was substituted for the solid fly-wheel of the ordinary gyrostat. In the instrument actually exhibited the equatorial diameter of the liquid shell exceeded the polar axis by about one tenth of either.

Supposing the rotational speed to be thirty turns per second, the effect of any motive which, if acting on a rotating solid of the same mass and dimensions, would produce a precession having its period a considerable multiple of $\frac{1}{3}$ of a second, must, according to theory, produce very approximately the same precession in the thin shell filled with liquid as in the rotating solid. Accordingly the main precessional phenomena of the liquid gyrostat were not noticeably different from those of ordinary solid gyrostats, which were shown in action for the sake of comparison. It is probable that careful observation without measurement might show very sensible differences between the performances of the liquid and the solid gyrostat in the way of nutational tremors produced by striking the case of the instrument with the fist.

No attempt at measurement either of speeds or forces was included in the communication, and the author merely showed the liquid gyrostat as a rough general illustration, which he hoped might be regarded as an interesting illustration of that very interesting result of mathematical hydrokinetics, the quasi-rigidity produced in a frictionless liquid by rotation.

P.S.—Since the communication of this paper to the Association, and the delivery of my opening address which preceded it on the same day, I have received from Prof. Henry No. 240 of the 'Smithsonian Contributions to Knowledge,' of date October 1871, entitled "Problems of Rotatory Motion presented by the Gyroscope, the Precession of the Equinoxes, and the Pendulum," by Brevet-Major Gen. J. G. Barnard, College of Engineers, U.S.A., in which I find a dissent from the portion of my previously published statements which I had taken the occasion of my address to correct, expressed in the following terms:—

"I do not concur with Sir William Thomson in the opinions quoted in note, p. 38, from Thomson and Tait, and expressed in his letter to Mr. G. Poulett Scrope ('Nature,' Feb. 1, 1872), so far as regards fluidity or imperfect rigidity, within an infinitely rigid envelope, I do not think the rate of precession would be affected."

Elsewhere in the same paper Gen. Barnard speaks of "the practical rigidity conferred by rotation." Thus he has anticipated my correction of the statements contained in my paper on the rigidity of the earth, so far as regards the effect of interior fluidity on the precessional motion of a perfectly rigid ellipsoidal shell filled with fluid.

I regret to see that the other error of that paper which I corrected in my opening address had not been corrected by Gen. Barnard, and that the plausible reasoning which had led me to it had also seemed to him convincing. For myself I can only say that I took the very earliest opportunity to correct the errors after I found them to be errors, and that I deeply regret any mischief they may have done in the mean time.

Addendum.

Solid and Liquid Gyrostats.—The solid gyrostat has been regularly shown for many years in the natural philosophy class of the University of Glasgow as a mechanical illustration of the dynamics of rotating solids, and it has also been exhibited in London and Edinburgh at conversaziones of the Royal Societies and of the Society of Telegraph Engineers, but no account of it has yet been published. The following is a brief description of it.

The solid gyrostat consists essentially of a massive fly-wheel, possessing great moment of inertia, pivoted on the two ends of its axis in bearings attached to an outer case which completely encloses it. Fig. 1 represents a section by a plane through the axis of the fly-wheel, and fig. 2 a section by a plane at right angles to the axis and cutting through the case just above the fly-wheel. The containing-case is fitted with a thin projecting edge in the plane of the fly-wheel, which is called the bearing-edge. Its boundary forms a regular curvilinear polygon of sixteen sides with its centre at the centre of the fly-wheel. Each side of the polygon is a small arc of a circle of radius greater than the distance of the corners from the centre. The friction of the fly-wheel would, if the bearing-edge were circular, cause the case to roll along it like a hoop; and it is to prevent this effect that the curved polygonal form described above and represented in the drawing is given to the bearing-edge.

To spin the solid gyrostat a piece of stout cord about forty feet long and a place where a clear run of about 60 feet can be obtained are convenient. The gyrostat having been placed with the axis of its fly-wheel vertical, the cord is passed in through an aperture in the case two and a half times round the bobbin-shaped part of the shaft and out again at an aperture on the opposite side. Having taken

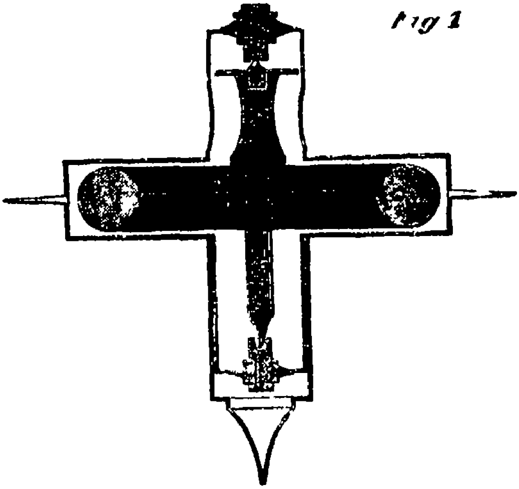


Fig 1

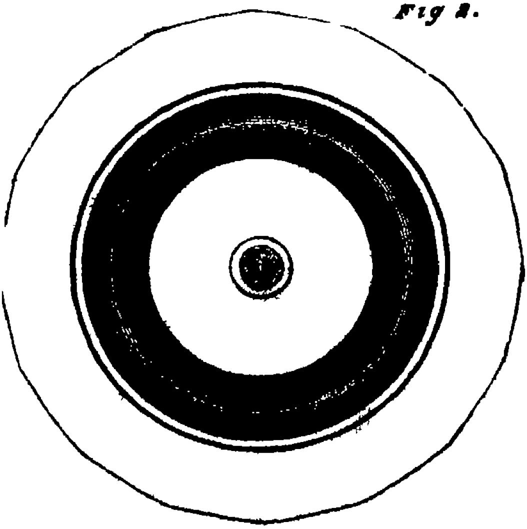


Fig 2.

Fig 3

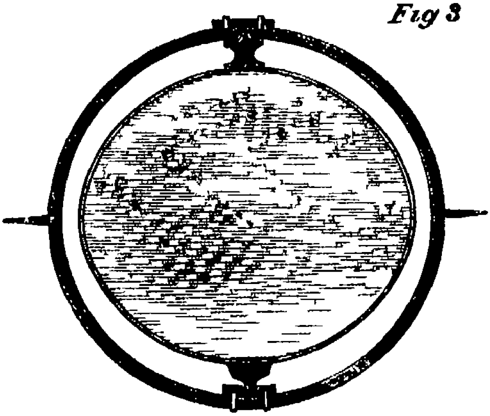
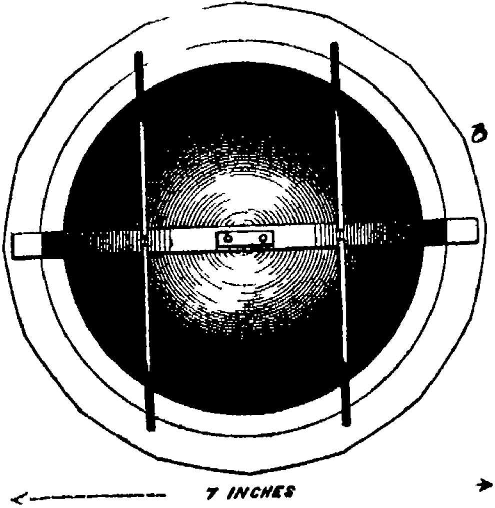


Fig 4



care that the slack cord is placed clear of all obstacles, and that it is free from kinks, the operator holds the gyrostat steady, so that its case is prevented from turning while an assistant pulls the cord through by running, at a gradually increasing pace, away from the instrument, while holding the end of the cord in his hand Sufficient tension is applied to the entering cord to prevent it from slipping round on the shaft In this way a very great angular velocity is communicated to the fly-wheel, sufficient, indeed to keep it spinning for upwards of twenty minutes

If, when the gyrostat has been spun it be set on its bearing edge with the centre of gravity exactly over the bearing point on a smooth horizontal plane such as a piece of plate glass lying on a table, it will continue apparently stationary and in stable equilibrium If while it is in this position a couple round a horizontal axis in the plane of the fly-wheel be applied to the wheel, no deflection of this plane from the vertical is produced, but it rotates slowly round a vertical axis If a heavy blow with the fist be given to the side of the case, it is met by what seems to the senses the resistance of a very stiff elastic body, and, for a few seconds after the blow, the gyrostat is in a state of violent tremor, which, however, subsides rapidly As the rotational velocity gradually diminishes, the rapidity of the tremors produced by the blow also diminishes It is very curious to notice the tottering condition, and slow, seemingly palsied tremulousness of the gyrostat when the fly-wheel has nearly ceased to spin

In the liquid gyrostat the fly-wheel is replaced by an oblate spheroid, made of thin sheet-copper and filled with water The ellipticity of this shell in the instrument exhibited is $\frac{1}{10}$—that is to say, the equatorial diameter exceeds the polar by that fraction of either It is pivoted on the two ends of its polar axis in bearings fixed in a circular ring of brass surrounding the spheroid This circle of brass is rigidly connected with the curved polygonal bearing edge which lies in the equatorial plane of the instrument, thus forming a framework for the support of the spheroidal shell In fig 3 a section is represented through the polar axis to show the ellipticity, and fig 4 gives a view of the gyrostat as seen from a point in the prolongation of the axis To prevent accident to the shell when the gyrostat falls down at the end of its spin cage bars are fitted round it in such a way that no plane can touch the shell

The method of spinning the liquid gyrostat is similar to that described for the solid gyrostat, differing only in the use of a very much longer cord and of a large wheel for the purpose of pulling it The cord is first wound on a bobbin free to rotate round a fixed pin The end of it is then passed two and a half times round a little pulley, and thence to a point in the circumference of a large wheel to which it is fixed An assistant then turns the wheel with gradually increasing velocity, while the frame of the gyrostat is firmly held, and the requisite tension applied to the entering cord to prevent it from slipping round the pulley

Secular Illustration of the Laws of the Diffusion of Liquids

By Sir W Thomson, *D C L , F R S*

On a new case of Instability of Steady Motion

By Sir W Thomson, *D C L , F R S*

On the Nutation of a Solid Shell containing Liquid

By Sir W Thomson, *D C L , F R S*

LIGHT AND HEAT.

Photometric Measurements of the Magneto-electric Light. By Captain ABNEY, F.R.S.

Determination of the Conductivity of Heat by Water. By J. T. BOTTOMLEY.

On the Testings of Large Objectives. By HOWARD GRUBB, *Master of Engineering, Trinity College, Dublin.*

In the testing of large objectives when the corrections have been made to be very nearly perfect, a difficulty is sometimes felt in determining what, if any, corrections remain desirable, and also of determining in a simple way the amount of the desired alteration.

For the chromatic aberration one plan often pursued by the optician is to slightly overcorrect the objective in the first instance and then to separate the crown and flint (thus reducing the correction) until the best result is attained, when the amount of separation required becomes by a simple calculation a measure of the necessary alteration in the curves.

This is an extremely useful practical arrangement, but unfortunately it is applicable to only one of the four possible errors, besides being troublesome and somewhat dangerous in the case of large objectives.

The desirability of some simple plan of introducing, *pro tempore*, a small + or − effect of chromatic or spherical aberration and of being able to accurately estimate the quantity of such has been very apparent to me on several occasions, for I have frequently found the best judges of such matters differ in their estimate of final correction, and unable to agree thereon, and I have also often found a difficulty in satisfying myself that the best balance of corrections had been attained, whereas if it were possible to introduce a small amount, *pro tempore*, of + or − correction, I could at once have perceived when I had overshot the mark. In fact the perfection of any correction in an objective means the *best balance between two opposing aberrations*, and (just as in all cases of ascertaining balances) it is difficult to determine the neutral point unless there be the power of trying on both sides.

To effect this, in preparing for the trial of the great objective for the new Observatory at Vienna (of 27 inches aperture) I am constructing four lenses or combination of lenses capable of being mounted between the objective and ocular and with a considerable range of motion in the axis of the telescope:—

A. While it effects no other correction introduces a small amount of + chromatic aberration.
B. Similarly introduces a small amount of − chromatic aberration.
C. „ „ + spherical aberration.
D. „ „ − spherical aberration.

The amount of any aberration introduced can be regulated by the position of the correcting lens in the pencil of rays.

Now, knowing the construction of these combinations and their position in the pencil of rays from objective to ocular, the corresponding correction in the objective is an easily calculable quantity. Quite apart from the use to the optician I believe the comfort of these appliances will be much appreciated by those appointed as judges, particularly where, as in the case of the Vienna telescope, the testing of the objective forms part of the work of a Committee composed of a considerable number of Members.

I have already experimented in this direction sufficiently to convince myself of the great value of this system so far as the correction for chromatic aberration is concerned, but I have not as yet experimented on the spherical aberration, nor am I so sanguine of its success.

There seems another direction in which a possible advantage might be gained by use of these correcting combinations, viz. in the case of minute stars whose light is made up for a great part of rays from either end of the spectrum, more particularly the blue end. It seems highly probable that better definition of these stars could be obtained if a slight temporary adjustment could be made in the chromatic correction suitable for that particular part of the spectrum from which the predominant light of the stars proceeds.

Of course it is to be understood that the corrections here spoken of and proposed to be dealt with by their correcting lenses are only the very final ones—in fact, when the objective arrives at that degree of perfection in which it is almost impossible to say whether any improvement can be effected or not.

On Recent Improvements in Equatorial Telescopes.

By HOWARD GRUBB, *Master of Engineering, Trinity College, Dublin.*

The author referred to former papers read by him at the Brighton and Belfast Meetings of the Association on the same subject, and proceeded to describe—

1st. A method of conveniently reading the R. A. circle from the eye-end of the telescope.

2nd. A new simple but effective arrangement for slow motion in R. A.

3rd. A new and very much improved form of clamping arrangement for both polar and declination axes.

4th. And a new method of controlling the uniform motion driving-clock of the telescopes from an ordinary sidereal clock by an electric current transmitted once a second from the sidereal clock, by which arrangement the driving-clock can be kept going continuously without the possibility of accumulation of errors beyond a small fraction of a second.

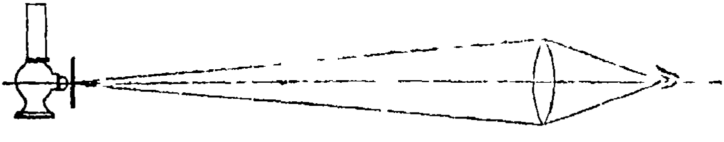
On a Method of Photographing the Defects in Optical Glass arising from want of Homogeneity.

By HOWARD GRUBB, *Master of Engineering, Trinity College, Dublin.*

The best practical method used for detecting in disks of optical glass defects arising from want of homogeneity is probably well known to many amateurs as well as to professional opticians.

The disk of glass to be examined should be either itself polished to a convex form, or, if that be not convenient, it should be placed in juxtaposition with a piece of glass which is known to be perfect and of such form as will render the combination of the two of convex power. A small light (say gas- or candle-flame, or any sufficiently brilliant light with a small diaphragm in front, see fig. 1) is placed at some

Fig. 1.



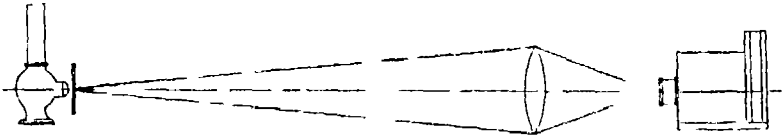
little distance, and the eye is placed in the conjugate focus formed by the lens of this light. The disk of glass should then appear brilliantly illuminated, but if the pupil of the eye is drawn slightly to one side, so that the pencil of light falls upon only one half of the pupil, immediately and most distinctly almost any want of homogeneity is easily seen.

I say "*almost* any want of homogeneity," because, with one exception, I believe any kind can be detected, but I have met, very rarely, instances of one peculiar class of this defect which it is not possible to detect till the disk is actually worked into an objective this happens when a slight gradual change of density occurs between two portions of the disk with no abrupt line of separation between.

Now this process, though a very simple one to a practised eye, is by no means so to an uneducated one, and I have often desired a method by which I could graphically represent those faults so that I might be able to communicate to others my ideas as to their exact forms and appearance, position in the disk, and so forth, and also to form a record of them This, by a very simple contrivance I have succeeded in doing, and I am now able to photograph these defects in optical glass with perfect certainty

A glance at the diagram will suffice to show the principle by which this is effected

Fig 2



The eye in the first instance (that of eye observation, fig 1) is replaced in the second case (fig 2) by a photo-camera, and, with a little care in adjusting the image of diaphragm illuminated by a lamp on the diaphragm of photo-lens, very excellent photographs can be obtained In fact the stop of the lens replaces the pupil of the eye, the photo-lens the crystalline lens and the sensitized plate the retina

The defects arising from want of homogeneity in optical glass may be divided into three classes —

1 Threads, or fine seams of some different quality of glass passing through the otherwise homogeneous disk, sometimes insignificant, sometimes long, but very rarely of any width These are of but little importance

2 Veins, or syrupy bands These are portions of glass of differing and various densities not properly amalgamated together Their appearance is that produced by adding a strong syrup solution to water The forms of these veins are sometimes very fantastic

This form of defect is very detrimental to the proper performances of the glass

3rd Sometimes, but very rarely (only four times in my experience), have I met with disks of glass having a density slightly different in different parts, without any well-defined line of demarcation between the different parts This is most destructive to its performance as an objective, and a most dangerous fault, for whereas in the two former cases the defects can be easily detected and even photographed, this third defect defies detection until the disks be formed into an objective

It is fortunate for opticians that this last defect is of such rare occurrence

The extreme usefulness of this simple device for photographing the defects in optical glass is self evident

In the first place, faults can be detected by those whose eyes have not been sufficiently educated to perceive them by the old method, a record can be made of any remarkable defects, their appearance and form can be graphically represented and described, and, lastly, it can be ascertained by this process whether the veins are closer to one or other surfaces and are capable of being removed by grinding, a point which is very difficult indeed to ascertain otherwise This last information is obtained by photographing the faults and then grinding off a small quantity, and rephotographing and comparing the photographs to see if any parts have disappeared Many other useful purposes seem to be too self-evident to require mentioning

On the Decrease of Temperature with Height on the Earth's Surface

By Professor HENNESSY, *F R S*

If the air were perfectly still, the temperature at any point in the atmosphere would depend on its density, the heat absorbed from the solar rays, the heat obtained by convection from the earth, and the losses of heat by radiation

Of these the first has been almost exclusively considered This is especially so in all investigations for the ascertainment of heights by the barometer The exclusion of the other causes of variation of temperature with height may be admissible in considering the condition of a vertical column of air resting on a horizontal plane, but the problem assumes a very different character when the decrease of temperature with height along a very gradually sloping surface is considered Such a surface is constantly communicating its temperature by convection currents to the overlying air, and the temperature of this air will depend on the extent form and physical properties of the underlying surface If we suppose a flat plain on the level of the sea, an observer in a balloon at a height of 1000 feet would find the temperature almost unaffected by convection and dependent upon density If now a steep mountain is superimposed on the plain and reaching to the observer the conditions become altered If a mountain of a gradual slope be superimposed the alteration will be still greater, and if the entire plain were elevated up to 1000 feet so as to form an extensive tableland, the change of conditions would be very remarkable

It follows that the law of variation of temperature with height above the level of the sea cannot be considered as uniform The decrease is most rapid in going up through a vertical column of air, as in balloon ascents It is slower along mountain sides, and slowest along gradually sloping plains or tablelands

From an examination of the records of many observations it appears that the decrease of temperature in balloon ascents is nearly one degree Fahrenheit for 300 feet, while for tablelands it is so slow as from 500 to 800 feet for one degree

The author referred to a number of observations made in different countries confirming the general conclusions to which he has been led

On the Distribution of Temperature over the British Islands

By Professor HENNESSY, *F R S*

The author referred to his former researches on the distribution of temperature over islands surrounded by heat-bearing currents and his demonstration that many of the isothermal lines in such islands must necessarily be closed curves* He had originally illustrated his conclusions by the results of observations taken in the British Islands, and the isothermal lines laid down from such observations were found to be in perfect harmony with the law he had proved In order to render this manifest he tabulated together the temperature of each, stating its latitude, longitude, height above the sea, and horizontal distance from the nearest sea coast The actual temperature of any place is affected by all of these elements In laying down the isothermal lines the actual temperatures unaltered by any so-called correction for height were always employed The stations were arranged according to temperature, and thus isothermal groups were immediately discovered If the more recent collection of temperature results for the British Isles compiled by Mr Buchan in the Journal of the Scottish Meteorological Society be treated in this way and the arbitrary and erroneous addition of 1° per every 300 feet in height be omitted, his results will conform to the law enunciated by the author

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* See Brit Assoc Rep 1857 pt 2 p 30 Atlantis, i 1858 pp 396–413 Phil Mag xvi 1858, p 241, Royal Society Proc ix p 324 'On the Laws which regulate the Distribution of Isothermal Lines Atlantis, ii p 201 American Journal of Science, xxvii p 328 Copies of the temperature maps are also partly reproduced in Report of Horticultural Congress at London in 1866 Journal of the R Dublin Society vol for 1870-71 Report of the Commission on Oyster Fisheries, 1871

Sur les Usages du Revolver Photographique en Astronomie et en Biologie. By Dr J. JANSSEN.

Photographies du Passage de Vénus à Kobé. By Dr J. JANSSEN.

Sur le Mirage en Mer. By Dr. J. JANSSEN.

On Solar Photography, with reference to the History of the Solar Surface. By Dr J. JANSSEN.

On the Eclipse of the Sun observed at Siam in April 1875. By Dr J. JANSSEN.

On Rotation of the Plane of Polarization by Reflection from a Magnetic Pole. By JOHN KERR, *LL.D., Mathematical Lecturer of the Free Church Training College, Glasgow*.*

In these experiments a beam of light is polarized by a first Nicol, reflected regularly from the end of an electromagnetic core of soft iron, and analyzed by a second Nicol. The magnetic force is concentrated intensely upon the mirror by means of a massive wedge of soft iron, which is separated from it by a narrow chink. The light is incident upon the polar mirror at an angle of 60° to 80°, the plane of polarization coincides with the plane of incidence, and the two Nicols are exactly crossed, so that the reflected light is extinguished by the second Nicol.

First Experiment.—When the iron mirror is intensely magnetized as N. pole or S. pole, the light is distinctly restored from pure extinction, to disappear at once when the circuit of the magnetizing current is broken.

Second Experiment.—The first Nicol is turned from its initial position through an extremely small angle—(1) to the right, (2) to the left (from the point of incidence on the iron mirror as point of view), so that the reflected light is restored very faintly through the second Nicol. When the mirror becomes an intense S. pole, the effects of rotations (1) and (2) are strengthened and weakened respectively; on the contrary, when the mirror becomes an intense N. pole, the effects of rotations (1) and (2) are weakened and strengthened respectively.

In the two remaining experiments the optical effects of the preceding rotations (1) and (2) and of magnetizations S. and N. of the mirror are compensated separately. The compensator is a slip of plate-glass, held in a standard position between the mirror and the second Nicol and strained by the hands. The angle of incidence is about 75°.

Third Experiment.—The first Nicol is turned from its initial position through an extremely small angle—(1) to the right, (2) to the left, so that the light is faintly restored from extinction by the second Nicol. The effects of displacement (1) and (2) are compensated, down to pure extinction, by tension and compression respectively.

Fourth Experiment.—A repetition of the first, with addition of the compensator. The effects of magnetizations S. and N. of the mirror are compensated, down to pure extinction, by tension and compression respectively.

The case of perpendicular incidence was tried carefully, but gave no good effect, the arrangements being comparatively imperfect. From the facts observed, it follows evidently that when a beam of plane polarized light is reflected from a magnetic pole, the plane of polarization is turned in the process of reflexion—to the left by a south-seeking pole, to the right by a north-seeking pole, so that in this case of reflection from iron, as in most cases of transmission through salts of iron, the plane of polarization is turned in a direction contrary to that of the magnetizing current.

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* A full account of this investigation is given in the Phil. Mag., May 1877.

A Description of Spottiswoode's Pocket Polarizing Apparatus. By W. Ladd.

On a Phenomenon of Metallic Reflection. By Professor G. G. Stokes, *F.R.S.*

The phenomenon which I am about to describe was observed by me many years ago, and may not improbably have been seen by others; but as I have never seen any notice of it, and it is in some respects very remarkable, I think that a description of it will not be unacceptable.

When Newton's rings are formed between a lens and a plate of metal, and are viewed by light polarized perpendicularly to the plane of incidence, we know that, as the angle of incidence is increased, the rings, which are at first dark-centred, disappear on passing the polarizing angle of the glass, and then reappear white-centred, in which state they remain up to a grazing incidence, when they can no longer be followed. At a high incidence the first dark ring is much the most conspicuous of the series.

To follow the rings beyond the limit of total internal reflection we must employ a prism. When the rings formed between glass and glass are viewed in this way, we know that as the angle of incidence is increased the rings one by one open out, uniting with bands of the same respective orders which are seen beneath the limit of total internal reflection; the limit or boundary between total and partial reflection passes down beneath the point of contact, and the central dark spot is left isolated in a bright field.

Now when the rings are formed between a prism with a slightly convex base and a plate of silver, and the angle of incidence is increased so as to pass the critical angle, if common light be used, in lieu of a simple spot we have a ring, which becomes more conspicuous at a certain angle of incidence well beyond the critical angle, after which it rapidly contracts and passes into a spot.

As thus viewed the ring is, however, somewhat confused. To study the phenomenon in its purity we must employ polarized light, or, which is more convenient, analyze the reflected light by means of a Nicol's prism.

When viewed by light polarized in the plane of incidence, the rings show nothing remarkable. They are naturally weaker than with glass, as the interfering streams are so unequal in intensity. They are black-centred throughout, and, as with glass, they open out one after another on approaching the limit of total reflection and disappear, leaving the central spot isolated in the bright field beyond the limit. The spot appears to be notably smaller than with glass under like conditions.

With light polarized perpendicularly to the plane of incidence, the rings pass from dark-centred to bright-centred on passing the polarizing angle of the glass, and open out as they approach the limit of total reflection. The last dark ring to disappear is not, however, the first, but the second. The first, corresponding in order to the first bright ring within the polarizing angle of the glass, remains isolated in the bright field, enclosing a relatively, though not absolutely, bright spot. At the centre of the spot the glass and metal are in optical contact, and the reflection takes place accordingly and is not total. The dark ring, too, is not absolutely black. As the angle of internal incidence increases by a few degrees, the dark ring undergoes a rapid and remarkable change. Its intensity increases till (in the case of silver) the ring becomes sensibly black; then it rapidly contracts, squeezing out, as it were, the bright central spot, and forming itself a dark spot, larger than with glass, isolated in the bright field. When at its best it is distinctly seen to be fringed with colour, blue outside, red inside (especially the former), showing that the scale of the ring depends on the wave-length, being greater for the less refrangible colours. This rapid alteration taking place well beyond the critical angle is very remarkable. Clearly there is a rapid change in the reflective properties of the metal, which takes place, so to speak, in passing through a certain angle determined by a sine greater than unity.

I have described the phenomenon with silver, which shows it best; but speculum-metal, gold, and copper show it very well, while with steel it is far less conspicuous. When the coloured metals gold and copper are examined by the light of a pure spectrum, the ring is seen to be better formed in the less than in the more refrangible colours, being more intense when at its best; while with silver and speculum-metal there is little difference, except as to size, in the different colours. Hæmatite and iron pyrites, which approach the metals in opacity and in the change of phase which they produce by reflection of light polarized parallel relatively to light polarized perpendicularly to the plane of incidence, do not exactly form a ring isolated in a bright field; but the spot seen with light polarized perpendicularly to the plane of incidence is abnormally broad just about the limit of total reflection, and rapidly contracts on increasing the angle of incidence.

It seemed to me that a sequence may be traced from the rapidly contracting rings of diamond seen in passing the polarizing angle of that substance through the abnormally broad and rapidly contracting spot seen with iron pyrites just about the limit of total reflection, and the somewhat inconspicuous ring of steel seen a little beyond the limit, to the intense rapidly contracting ring of silver seen considerably beyond the limit. If so, the full theory of the ring will not be contained in the usually accepted formulæ for metallic reflection modified, as in the case of transparent substances, in accordance with the circumstance that the incidence on the first surface of the plate of air is beyond that of total reflection.

MacCullagh was the first to obtain the formulæ for metallic reflection, showing that they were to be deduced from Fresnel's formulæ by making the refractive index a mixed imaginary, though they are usually attributed to Cauchy, who has given formulæ differing from those of MacCullagh merely in algebraic detail. As regards theory Cauchy made an important advance on what MacCullagh had done in connecting the peculiar optical properties of metals with their intense absorbing power[*]. Now Fresnel's formulæ do not include the phenomena discovered by Sir George Airy which are seen in passing the polarizing angle of diamond, and which have been more recently extended by M. Jamin to the generality of transparent substances; and if these pass by regular sequence to those I have described as seen with metals beyond the limit of total internal reflection, it follows that the latter would not be completely embraced in the application of Fresnel's formulæ, modified to suit an intensely absorbing substance and an angle of incidence given by a sine greater than unity[†].

Electricity.

On the Contact Theory of Voltaic Action. By Professors AYRTON *and* Pi

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On a new Form of Electrometer. By Prof. J. DEWAR, *F.R.S.E.*

On a Mechanical Illustration of Electric Induction and Conduction.

By OLIVER J. LODGE, *B.Sc.*

The paper describes the construction of a model which illustrates Prof. Clerk Maxwell's theory of electric action on the hypothesis of stress in a dielectric medium, and which consists essentially of an endless cord passing with friction through buttons supported on elastic strings. By altering the relation between the friction and the elasticity of different parts, it can be made to exhibit very completely the phenomena observed when an electromotive force is made to act:—(1) between the ends of a metal wire; (2) through an electrolytic liquid: when it illustrates the convection of electricity by the cathion and the polarization of the electrode; (3) in an accumulator with perfectly insulating dielectric, when it shows the polarization of the dielectric, the displacement of electricity in the direction of the force, the tension along the lines of force, occasional possible disruptive discharge, and consequent possible internal charge; (4) across a dielectric which is homogeneous, but has a slight conducting power, showing in this case a continuous ordinary conduction-current, in addition to the variations of electric displacement; (5) across a non-homogeneous or stratified dielectric in which a 'residual charge' is possible. If made of proper materials, the model would exhibit this residual charge quantitatively as well as qualitatively; and, in fact, the investigation "On the Theory of a Composite Dielectric" (in arts. 328–330 of Maxwell's 'Electricity') would apply to it with little modification. It further illustrates incidentally the action of a voltaic cell and of a submarine cable.

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[*] The apparent difference between MacCullagh and Cauchy as to the values of the refractive indices of metals is merely a question of arbitrary nomenclature.

[†] It was long ago observed both by Professor MacCullagh and Dr. Lloyd that when Newton's rings are formed between a glass lens and a metallic plate, the first dark ring surrounding the central spot, which is comparatively bright, remains constantly of the same size at high incidences, although the other rings, like Newton's rings formed between two glass lenses, dilate greatly as the incidence becomes more oblique. See Proceedings of the Royal Irish Academy, vol. i. p. 6.

On a Mechanical Illustration of Thermoelectric Phenomena.

By Oliver J. Lodge, *B.Sc.*

The model which illustrates metallic conduction in the preceding communication is supposed to be modified so that all the buttons execute very rapid isochronous simple harmonic motions, sliding to and fro on the cord. The rate of cooling of a body placed in an enclosure at absolute zero is then seen to be proportional to the absolute temperature of the body, and to depend on its specific electrical resistance. The electric condition of tourmaline is explained by an hypothesis as to the nature of its internal structure; and the amount of heat generated by an electric current passing through a metallic conductor is deduced in accordance with Joule's law. An hypothesis is then started as to the nature of the internal actions at a junction either of two different metals at the same temperature or of two parts of the same metal at different temperatures; and, on the strength of this hypothesis, electromotive force produced by contact, the Peltier effect, and Thomson's electric convection of heat are all illustrated. The exact laws which have been experimentally established for these effects may possibly be deducible from considerations founded on the model; but this has not yet been properly done.*

On the Protection of Buildings from Lightning.

By Professor J. Clerk Maxwell, *F.R.S.*

Most of those who have given directions for the construction of lightning-conductors have paid great attention to the upper and lower extremities of the conductor. They recommend that the upper extremity of the conductor should extend somewhat above the highest part of the building to be protected, and that it should terminate in a sharp point, and that the lower extremity should be carried as far as possible into the conducting strata of the ground, so as to "make" what telegraph engineers call "a good earth."

The electrical effect of such an arrangement is to *tap*, as it were, the gathering charge, by facilitating a quiet discharge between the atmospheric accumulation and the earth. The erection of the conductor will cause a somewhat greater number of discharges to occur at the place than would have occurred if it had not been erected, but each of these discharges will be smaller than those which would have occurred without the conductor. It is probable, also, that fewer discharges will occur in the region surrounding the conductor. It appears to me that these arrangements are calculated rather for the benefit of the surrounding country, and for the relief of clouds labouring under an accumulation of electricity, than for the protection of the building on which the conductor is erected.

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* These two papers are published, with some additions in the Phil. Mag. ser. 5, vol. ii. pp. 353 and 524.

What we really wish is to prevent the possibility of an electric discharge taking place within a certain region, say, the inside of a gunpowder manufactory.

If this is clearly laid down as our object, the method of securing it is equally clear.

An electric discharge cannot occur between two bodies unless the difference of their potentials is sufficiently great compared with the distance between them. If, therefore, we can keep the potentials of all bodies within a certain region equal or nearly equal, no discharge will take place between them. We may secure this by connecting all these bodies by means of good conductors, such as copper wire ropes, but it is not necessary to do so, for it may be shown by experiment that if every part of the surface surrounding a certain region is at the same potential, every point within that region must be at the same potential, provided no charged body is placed within the region.

It would therefore be sufficient to surround our powder mill with a conducting material (to sheathe its roof, walls, and ground floor with thick sheet-copper) and then no electrical effect could occur within it on account of any thunder-storm outside.

There would be no need of any earth connexion. We might even place a layer of asphalt between the copper floor and the ground, so as to insulate the building. If the mill were then struck with lightning, it would remain charged for some time, and a person standing on the ground outside and touching the wall might receive a shock; but no electrical effect would be perceived inside, even on the most delicate electrometer. The potential of everything inside with respect to the earth would be suddenly raised or lowered, as the case might be; but electric potential is not a physical condition but only a mathematical conception, so that no physical effect could be perceived.

It is therefore not necessary to connect large masses of metal, such as engines, tanks, &c. to the walls, if they are entirely within the building.

If, however, any conductor, such as a telegraph-wire or a metallic supply-pipe for water or gas, comes into the building from without, the potential of this conductor may be different from that of the building, unless it is connected with the conducting shell of the building. Hence the water or gas supply-pipes, if any enter the building, must be connected to the system of lightning-conductors; and since to connect a telegraph-wire with the conductor would render the telegraph useless, no telegraph from without should be allowed to enter a powder-mill, though there may be electric bells and other telegraphic apparatus entirely within the building.

I have supposed the powder-mill to be entirely sheathed in thick sheet-copper. This, however, is by no means necessary in order to prevent any sensible electric effect taking place within it supposing it struck by lightning. It is quite sufficient to enclose the building with a network of a good conducting substance. For instance, if a copper wire, say No. 4, B.W.G. (0.238 inch in diameter), were carried round the foundation of a house, up each of the corners and gables, and along the ridges, this would probably be a sufficient protection for an ordinary building against any thunder-storm in this climate. The copper wire may be built into the wall to prevent theft, but it should be connected to any outside metal, such as lead or zinc on the roof, and to metal rain-water pipes.

In the case of a powder-mill, it might be adviseable to make the network closer by carrying one or two additional wires over the roof and down the walls to the wire at the foundation. If there are water- or gas-pipes which enter the building from without, these must be connected with the system of conducting-wires; but if there are no such metallic connexions with distant points, it is not necessary to take any pains to facilitate the escape of the electricity into the earth.

It is desirable, however, to provide for the safety not only of the building itself, but of the system of conductors which protects it. The only parts of this system which are in any danger are the points where the electricity enters and leaves it. If, therefore, the system terminates above in a tall rod with a sharp point, and downwards in an "earth wire," the external discharge will be almost certain to occur at the ends of these electrodes, and the only possible damage will be the loss of a few particles from their extremities, but even if the rod and wire were destroyed altogether, the building would still be safe.

On Compass Correction in Iron Ships. By Sir W. Thomson, *D.C.L.*, *F.R.S.*

Effects of Stress on the Magnetization of Iron.
By Sir W. Thomson, *D.C.L.*, *F.R.S.*

On Contact Electricity. By Sir W. Thomson, *D.C.L.*, *F.R.S.*

Acoustics.

On the Conditions of the Transformation of Pendulum-Vibrations, with an experimental illustration. By R. H. M. Bosanquet, *Fellow of St. John's College, Oxford.*

Under certain circumstances, a pendulum-vibration of given period can give rise to impulses which support vibrations whose periods are $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, . . of the period of the original vibration The conditions under which this takes place are of interest.

Wheatstone enunciated the following as an experimental law —A periodic impulse can sustain vibrations whose frequencies are multiples of that of the impulse.

This was supported by an experiment in which the harmonics of a Jew's harp are obtained from it by an adjustable resonator. But a general law cannot be proved by a particular experiment.

An experiment was adduced in contradiction of the generality of the above law It can be shown that the stopped pipes of the organ are incapable of supporting the vibration of resonators tuned to their octave and double octave, while open pipes are capable of doing so.

As the result of mechanical theory, the law may be enunciated that no pendulum-vibration can be maintained in a vibrating system, unless the acting forces contain impulses of the same period as the vibration maintained

The experiments commonly shown, in which a simple pendulum-vibration is made to support its harmonics, generally depend on a transformation of the vibration in the transmission of the impulse. The apparatus exhibited forms a type of the general process of transformation by transmission.

A metronome vibrating seconds furnishes the fundamental vibration a number of small pendulums vibrate 2, 3, 4, 5, 6, 7, and 8 times in a second. By making connexions between the metronome and the pendulums with elastic cord in different ways, the different kinds of transmission (with and without transformation) can be illustrated.

When the cord is tight, the impulses are transmitted without transformation; when the cord goes slack during the vibration, the impulses are transformed into a series of pulls. In the first case the small pendulums are not affected, in the second they are generally set in vibration.

The following points are illustrated by the experiment with the partly slack cord, where the impulses constitute a series of pulls :—

The common exposition of the theory of musical sounds, in which the impulses are compared to the blows of a hammer, really makes a very complex effect the basis of operations The notes thus constructed differ from simple musical tones in having the power of supporting the vibrations of their harmonics.

The cases of the notes of the siren and the harmonium, in which the sound is produced by a series of jets of air, are illustrated by the same experiment

An experiment of Prof. Mayer's, for the analysis of the sound of a reed pipe, by attaching a vibrating portion of it to tuning-forks, was discussed It was shown that the mode of transmission is such as to lead to transformation, whereby the analysis is vitiated

Mr J Baillie Hamilton's experiment, in which an harmonium reed is made to support the vibrations of a wire sounding its harmonics without actual attachment, was shown to be a case of transformation

The production of harmonics by resonance from the Jew's harp or harmonium-reeds without wind was discussed and it was shown that they may be regarded as giving rise to discontinuous impulses at the moment when they close the openings in which they fit

It was then shown how a series of discontinuous impulses may be expressed mathematically and from the fact that the expressions involve pendulum vibrations corresponding to the harmonics it was shown to follow that harmonic vibrations may be excited by such a series of impulses

The nature of the modification the expressions require for application to the siren was pointed out and it was thus explained how the siren tone comes to involve harmonics of considerable intensity

We now come to the problem of transformation of simple sound vibrations by transmission through air

An experiment was described in which a large tuning fork was presented to a series of resonators (organ pipes) tuned to its harmonics the result was that, with the fork alone, they were audible up to the tierce inclusive (harmonic of fifth order), and with a disk of wood fastened on to the prong they were audible up to the harmonic seventh inclusive

A mathematical investigation of the transformation of simple vibrations in air was then carried out, and applied to the above experiment It results that for the fifth harmonic of the fork, which was clearly heard, the flow of energy should be approximately

$$\frac{1}{2\times 10^{8}} \text{ foot pounds per second}$$

This seeming extraordinarily minute an experiment was made with a small tuning-fork of about the same pitch as the fifth harmonic above mentioned The time of diminution of the amplitude to $\frac{1}{10}$ was observed and the initial amplitude From this the amplitude was calculated at the subsequent time when the sound just ceased to be audible The flow of energy per second at this point was estimated approximately at

$$\frac{1}{4\times 10^{18}} \text{ foot pounds,}$$

which agrees pretty well with the above number deduced from theory

It was then pointed out that the intensity due to a given flow of energy is different in different parts of the scale Helmholtz has remarked this (p 264 of Ellis's Helmholtz), and, in a paper in the Philosophical Magazine (Nov 1872), the writer showed that, if we admit that in similar organ-pipes similar proportions of the energy of the wind supplied are converted into sound, the mechanical energy of notes of given intensity varies inversely as the vibration number a law in accordance with the indications given by Helmholtz

The theory was then applied to ascertain the extent of the development of harmonics in a tubular resonator tuned to the fundamental Such development turns out to be very considerable In consequence of this we cannot generally assume that the notes produced by resonators are simple tones The bearing of this on a recent important paper of Kœnig's was alluded to

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True Intonation, illustrated by the Voice-Harmonium with Natural Finger-board By COLIN BROWN

A series of harmonics forms an arithmetical progression, the number of the vibrations between any consecutive members of the series being equal The vibrations rapidly increase in velocity in the higher harmonics, while the musical intervals as rapidly decrease: the same number of vibrations which between the 1st and 2nd steps of the harmonic series produce an octave, between 2nd and 3rd step a fifth, between the 4th and 5th steps a major third, between the 15th and 16th steps produce only a diatonic semitone, and so onwards beyond the range of musical computation.

In contrast with this harmonic series of sounds, which is simple arithmetical, and perfectly regular, we have the series of the musical scale, which is compound, geometrical, and so irregular that two tones or steps of equal vibrations cannot musically succeed each other. Of the 48 sounds in the harmonic series 22 are coincident with the musical series, and 26 are not coincident.

Of these 22 coincidences, the root, or lowest sound of the harmonic series, occurs as—

The 4th sound of the musical scale	6 times
The 1st sound or Tonic, occurs	5 „
The 6th „ of the scale „	4 „
The 5th „ „ „	3 „
The 3rd „ „ „	2 „
The 2nd „ „ „	1 „
The 7th „ „ „	1 „
In all	22 „

Of these 22 coincidences between the harmonic series and the musical series, the last are the numbers 24, 27, 30, 32, 36, 40, 45, and 48, which form the relations of the musical scale.

This *full* harmonic series can *only* be built upon Fa, or the 4th of the musical scale, as its root; and the first power of Fa, 10⅔ (as it appears in the lowest series of the musical scale 8, 9, 10, 10⅔, 12, 13⅓, 15, 16) is the common multiplier and divisor of the vibrations of all the sounds of the musical scale. Thus in the octave from tenor C upwards the vibrations are:—

C	D	E	F	G	A	B	C
256,	288,	320,	341⅓,	384,	426⅔,	480,	512

These, divided by the first power of Fa, or the 4th of the musical scale (say 10⅔), give 24, 27, 30, 32, 36, 40, 45, 48, being the figures of the musical scale with which the harmonic series closes.

In this harmonic series the 8th, 9th, and 10th tones or steps following in diatonic succession are the 1st, 2nd, and 3rd tones of the musical scale, and the 15th and 16th are the 7th and 8th of the musical scale.

These figures give us the first or lowest relations of the musical scale, 8:9, 9:10, and 15:16:—

The large step or tone of	8:9	occurs	3 times
The less „ „	9:10	„	2 „
The small „ „	15:16	„	2 „
Within the octave, in all			7 steps or tones

These relations of the tones or steps of the scale are always the same in every key. C, =512 vibrations, is common to the keys of B♭, F, C, and G; and the 7th or diatonic semitone below, =480 vibrations, is common to the keys of C, G, and D, so with every musical tone. Each of these is represented by a digital upon the natural finger-board of the author's voice harmonium.

For distinction the digitals representing tones common to 4 keys are white, those to 3 keys are coloured; the 1st, 2nd, 4th and 5th tones of the scale in every key are white, and the 3rd, 6th, and 7th are coloured.

In every key, looking *along* the fingerboard, the progression of the scale is the same:—8:9, 9:10, 15:16, 8:9, 9:10, 8:9, 15:16. From white digital to white, or from coloured to coloured, there is always the large step or tone of the scale 8:9, from white to coloured always the less tone of the scale 9:10, and from coloured to white always the small step or tone 15:16, the diatonic semitone. Looking *across* the finger-board at the digitals endwise, from the end of each white digital to the end of the coloured immediately above it in direct line there is always the chromatic semitone of 128 : 135, and from the end of each coloured digital to the end of the white immediately above the comma of 80 : 81 always appears.

Between each white or flat note, as E♭, and each coloured or sharp note, as D♯, at the distance of six removes looking *across* the diagram or finger-board, the schisma of the scale is always found, 32,768 : 32,805.

The only other relation of the scale is represented by a round digital on the finger-board and by 7 *minor* on the diagram; it is tuned as 15 : 16 to the 6th of the major scale, and supplies the sharpened 7th and 6th tones of the modern minor scale; it also gives the imperfect chromatic semitone of 24 : 25 in relation to the 5th of the major scale.

This finger-board is termed "natural" because no extra digitals like the five black digitals of the ordinary keyboard are required to produce the chromatic tones. Every coloured digital is sharp in relation to the white below it, and every white digital is flat in relation to the coloured above it, the relation being always 128 : 135.

On this finger-board only 4 musical relations, viz. 8 : 9, 9 : 10, 15 : 16, and 128 : 135, are found, and 3 musical differences, viz. 24 : 25, 80 : 81, and 32,768 : 32,805.

All the larger intervals of the scale are formed by adding 8 : 9, 9 : 10, and 15 : 16 together; and all the smaller intervals are produced by subtracting or dividing these thus:—

8 : 9 less 15 : 16 = 128 : 135, the chromatic semitone;
9 : 10 „ 15 : 16 = 24 : 25, the imperfect chromatic semitone;
8 : 9 „ 9 : 10 = 80 : 81, the comma; and
8 : 9 „ 9 : 10 = 128 : 135, which being

squared and divided by 9 : 10, gives the schisma 32,768 : 32,805. Thus all the intervals and relations of the musical scale proceed from these three simple elements, 8 : 9, 9 : 10, and 15 : 16.

By adding a comma and a schisma together, the comma of Pythagoras is produced. This is always found between keys changed enharmonically, as from C♭ to B.

The three series of digitals upon this finger-board, white, coloured, and round, are very easily tuned by perfect fifths throughout, and connected together by major thirds. The tuning is diagonal, producing every interval perfectly in its proper place.

Tuned in this way, this instrument (within its range or compass) is mathematically and musically perfect, without compromise or approximation of any kind, and requiring neither equations, decimals, nor logarithms to explain it. It is very easily played upon.*

On a Practical Method of Tuning a Major Third.
By Sir W. Thomson, *D.C.L., F.R.S.*

INSTRUMENTS, &c.

On a Form of Gasholder giving a uniform Flow of Gas. *By* Prof. Barrett.

Diagrams and Description of the new Lecture-Table for Physical Demonstration in the Royal College of Science for Ireland. *By* Prof. Barrett.

On Forms of Apparatus for the Experimental Illustration of the Expansion of Solids by Heat. *By* Prof. Barrett.

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* The principles of construction, tuning, &c. of the voice harmonium will be found fully explained in 'Music in Common Things,' part ii. Collins and Co., London, Edinburgh and Glasgow.

On a Modification of the Sprengel Pump, and a new Form of Vacuum-Tap. *By* C. H. Gimingham.

On new Standards of Measure and Weight. *By* Prof. Hennessy, *F.R.S.*

On a new Form of Thermometer for observing Earth Temperature. *By* G. J. Symons.

On an Unmistakable True North Compass. *By* G. J. Symons.

The author said that it was not generally known, except to nautical and to scientific men, that the compasses usually sold did not point to the true North or South Pole of the earth. The magnetic Pole, to which all compass needles pointed, was not identical with the geographical pole, which was the north point of maps. The variation of the needle was considerable, and was no doubt often the cause of tourists losing their way. The difference between true and magnetic north was not the same in all parts of the United Kingdom, and *à fortiori* in all parts of the globe, nor was it absolutely the same from year to year. One of the advantages of these instruments was their pointing to the true north, the other was their 'unmistakableness.' These compasses were corrected for use in the United Kingdom, but could be adapted to any specified locality in any part of the world.

On a new Form of Astronomical Clock with Free Pendulum and Independently Governed Uniform Motion for Escapement-wheel. *By* Sir W. Thomson, *D.C.L., F.R.S.*

The object of this communication was to explain to members of the Association and give them an opportunity of seeing in the author's house in the University a clock which had been described in a communication to the Royal Society in 1869, entitled "On a New Astronomical Clock and a Pendulum Governor for Uniform Motion." The following description is taken from the 'Proceedings of the Royal Society' for 1869, except a few alterations and additions and the drawings, which have not been hitherto published:—

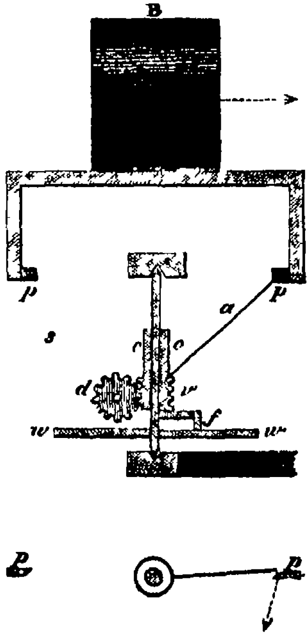
It seems strange that the dead-beat escapement should still hold its place in the astronomical clock, when its geometrical transformation, the cylinder escapement of the same inventor, Graham, only survives in Geneva watches of the cheaper class. For better portable time-keepers it has been altered through the vicious rack-and-pinion movement into the superlatively good detached lever. If it is possible to make astronomical clocks go better than at present by merely giving them a better escapement, it is quite certain that one on the same principle as the detached lever, or as Earnshaw's ship-chronometer escapement, would improve their time-keeping.

But the irregularities hitherto tolerated in astronomical clocks may be due more to the faultiness of the steel and mercury compensation pendulum, with its loosely attached glass jar, and of the mode in which it is hung, and of the instability of the supporting clock case or framework, than to imperfection of the escapement and the greatness of the arc of vibration which it requires; therefore it would be wrong to expect confidently much improvement in the time-keeping merely from improvement of the escapement. I have therefore endeavoured to improve both the compensation for change of temperature in the pendulum and the mode of its support, in a clock which I have recently made with an escapement on a new principle, in which the simplicity of the dead-beat escapement of Graham is retained, while its great defect, the stopping of the whole train of wheels by pressure of a tooth upon a surface moving with the pendulum, is remedied.

Imagine the escapement-wheel of a common dead-beat clock to be mounted on a collar fitting easily upon a shaft instead of being rigidly attached to it. Let friction be properly applied between the shaft and the collar, so that the wheel shall be carried round by the shaft unless resisted by a force exceeding some small definite amount, and let a governor giving uniform motion be applied to the train of wheel-work connected with this shaft, and so adjusted that, when the escapement-wheel is unresisted, it will move faster by a small percentage than it must move to keep time properly. Now let the escapement-wheel, thus mounted and carried round, act upon the escapement, just as it does in the ordinary clock. It will keep the pendulum vibrating, and will, just as in the ordinary clock, be held back every time it touches the escapement during the interval required to set it right again from having gone too fast during the preceding interval of motion. But in the ordinary clock the interval of rest is considerable, generally greater than the interval of motion. In the new clock it is equal to a small fraction of the interval of motion—$\frac{1}{300}$ in the clock as now working, but to be reduced probably to something much smaller yet. The simplest appliance to count the turns of this escapement-wheel (a worm, for instance, working upon a wheel with thirty teeth, carrying a hand round, which will correspond to the seconds hand of the clock) completes the instrument, for minute- and hour-hands are a superfluity in an astronomical clock.

In various trials which I have made since the year 1865, when this plan of escapement first occurred to me, I have used several different forms, all answering to the preceding description, although differing widely in their geometrical and mechanical characters. In all of them the escapement-wheel is reduced to a single tooth or arm, to diminish as much as possible the moment of inertia of the mass stopped by the pendulum. This arm revolves in the period of the pendulum (two seconds for a seconds pendulum), or some multiple of it. Thus the pendulum may execute many complete periods of vibration without being touched by the escapement. In all my trials the pallets have been attached to the bottom of the pendulum, projecting below it, in order that satisfactory action with a very small arc of vibration (not more on each side than $\frac{1}{100}$ of the radius, or 1 centimetre for the seconds pendulum) may be secured.

In the clock in my house the seconds pendulum of the fine movement vibrates with great constancy through half a millimetre, that is to say, through an arc of $\frac{1}{2000}$ of the radian on each side of the vertical. This, I believe, is the smallest range that has hitherto been realized in any seconds pendulum of an astronomical or other clock.



In the drawing *s* represents the vertical escapement-shaft, round which is fitted loosely the collar *c*, carrying the worm *v*. The small wheel, *d*, is worked by *v*, and carries round the seconds hand of the clock. *a* represents a piece of fine steel wire, being the single arm to which the teeth of the escapement-wheel are reduced in the clock described in this paper, *pp* the pallets attached to bars projecting downwards from the bob, B, of the pendulum, *f*, a foot bearing the weight of the collar-worm and escapement-tooth. The bar connecting *f* with the collar is of such a length as to give a proper moment to the frictional force by which the collar is carried round. The shaft *s* carries a wheel, represented in section by *w w*, which is driven by a train of wheel-work (not shown in the drawing) from the governor. This wheel is made to go ¼ per cent faster than once round in two seconds, while the pendulum prevents the collar from going round more than once in two seconds.

My trials were rendered practically abortive from 1865 until a few months ago by the difficulty of obtaining a satisfactory governor for the uniform motion of the escapement-shaft; this difficulty is quite overcome in the pendulum governor, which I now proceed to describe.

Imagine a pendulum with single tooth escapement mounted on a collar loose on the escapement-shaft just as described above, the shaft being vertical in this case also. A square-threaded screw is cut on the upper quarter of the length of the shaft, this being the part of it on which the escapement-collar works, and a pin fixed to the collar projects inwards to the furrow of the screw, so that, if the collar is turned relatively to the shaft, it will be carried along as the nut of a screw, but with less friction than an ordinary nut. Below the screw and long nut-collar three-quarters of the length of the escapement-shaft is surrounded by a tube which by wheel-work is carried round about 5 per cent. faster than the central shaft. This outer shaft, by means of friction produced by the pressure of proper springs, carries the nut-collar round along with it, except when the escapement-tooth is stopped by either of the pallets attached to the pendulum. A stiff cross-piece (like the head of a T), projecting each way from the top of the tubular shaft, carries, hanging down from it, the governing masses of a centrifugal friction governor. These masses are drawn towards the axis by springs, the inner ends of which are acted on by the nut-collar, so that the higher or the lower the latter is in its range the springs pull the masses inwards with less or more force. A fixed metal ring coaxial with the main shaft holds the governing masses in when their centrifugal forces exceed the forces of the springs, and resists the motion by forces of friction increasing approximately in simple proportion to the excess of the speed above that which just balances the forces of the springs. As long as the escapement-tooth is unresisted the nut-collar is carried round with the quicker motion of the outer tubular shaft, and so it *screws upwards*, diminishing the force of the springs. Once every semiperiod of the pendulum it is held back by either pallet, and the nut-collar screws *down* as much as it rose during the preceding interval of freedom, when the action is regular, and the central or main escapement shaft turns in the same period as the tooth, being the period of the pendulum. If through increase or diminution of the driving-power, or diminution or increase of the coefficient of friction between the governing masses and the ring on which they press, the shaft tends to turn faster or slower, the nut-collar works its way down or up the screw, until the governor is again regulated, and gives the same speed in the altered circumstances. It is easy to arrange that a large amount of regulating power shall be implied in a single turn of the nut-collar relatively to the central shaft, and yet that the periodic application and removal of about $\frac{1}{50}$ of this amount in the half-period of the pendulum shall cause but a *very small* periodic variation in the speed. The latter important condition is secured by the great moment of inertia of the governing masses themselves round the main shaft. My communication to the Royal Society ended as follows:—

"I hope after a few months trial to be able to present a satisfactory report of the performance of the clock now completed according to the principles explained above. As many of the details of execution may become modified after practical trial, it is unnecessary that I should describe them minutely at present. Its general appearance, and the arrangement of its characteristic parts, may be understood from the photograph now laid before the Society."

I am sorry to say that the hope here expressed has not hitherto been realized. Year after year passed producing only more or less of radical reform in various mechanical details of the governor and of the fine movement until about six months ago, when, for the first time, I had all except the pendulums in approximately satisfactory condition. By that time I had discovered that my choice of zinc and platinum for the temperature compensation and lead for the weight of the pendulums was a mistake. I had fallen into it about ten years ago through being informed that in Russia the gridiron pendulum had been reverted to because of the difficulty of getting equality of temperature throughout the length of the pendulum, and without stopping to perceive that the right way to deal with this difficulty was to face it and take means of securing practical equality of temperature throughout the length of the pendulum (which it is obvious may be done by simple enough appliances), I devised a pendulum in which the compensation is produced by a stiff tube of zinc and a platinum wire placed nearly parallel each to the other throughout the length of the pendulum, and the two pendulums of the clock shown to the British Association were constructed on this plan. Now it is clear that the materials chosen for compensation should, of all those not otherwise objectionable, be those of greatest and of least expansibility. Therefore, certainly, glass or platinum ought to be one of the materials, and the steel of the ordinary astronomical mercury pendulum is a mistake. Mercury ought to be the other (its cubic expansion being six times the linear expansion of zinc), unless the capillary uncertainty of the mercury surface lead to irregular changes in the rate of the pendulum. The weight of the pendulum ought to be of material of the greatest specific gravity attainable, at all events unless the whole is to be mounted in an air-tight case, because one of the chief errors of the best existing pendulums is that depending on the variations of barometric pressure. The expense of platinum puts it out of the question for the weight of the pendulum, even although the use of mercury for the temperature compensation did not also give mercury for the weight. Thus even though as good compensation could be got by zinc and platinum as by any other means, mercury ought, on account of its superior specific gravity, to be preferred to lead for the weight of the pendulum.

I have accordingly now made several pendulums (for tide-gauges) with no other material in the moving part than glass and mercury, with rounded knife-edges of agate for the fixed support, and I am on the point of making four more for two new clocks which I am having made on the plan which forms the subject of this communication. I have had no opportunity hitherto of testing the performance of any of these pendulums, but their action seems very promising of good results, and the only untoward circumstance which has hitherto appeared in connexion with them has been breakages of the glass in two attempts to have one carried safely to Genoa for a tide-gauge made by Mr. White to an order for the Italian Government.

As to the accuracy of my new clock, it is enough to look at the pendulum vibrating with perfect steadiness, from month to month, through a range of half a centimetre on each side of its middle position, with its pallets only touched during $\frac{1}{100}$ of the time by the escapement-tooth, to feel certain that, if the best ordinary astronomical clock owes any of its irregularities to variations of range of its pendulum, or to impulses and friction of its escapement-wheel, the new clock must, when tried with an equally good pendulum, prove more regular. I hope soon to have it tried with a better pendulum than that of any astronomical clock hitherto made; and if it then shows irregularities amounting to $\frac{1}{10}$ of those of the best astronomical clocks, the next step must be to inclose it in an air-tight case kept at constant temperature, day and night, summer and winter.

On Mr. Sabine's Method of Measuring small Intervals of Time.

By W. H. Walenn.

On Tidal Operations in the Gulf of Cutch by the Great Trigonometrical Survey of India. *By* Capt. A. W. Baird, *R.E.*

The primary object of the operations was to determine whether secular changes in the level of the land at the head of the Gulf, *i.e.* the "Rann of Cutch," are taking place. Col. Walker, the Superintendent of the Great Trigonometrical Survey of India, at first intended to restrict the observations to a few weeks duration; but he found that by extending them to a period of a little over a year, scientific results of the highest value would be obtained, and also that this course would be necessary in order to obtain data sufficient to detect minute changes in the relative level of land and sea. I was deputed when in England in 1871 to study the details of tidal observations and harmonic analysis as recommended by the British Association; at the same time I tested a new self-registering tide-gauge, the performances of which were very satisfactory. The self-registering tide-gauges were then described at length, the most remarkable feature in them being the unusually long barrels (length 5 feet), which were provided in order to give the tidal curves on the diagram on a very large scale. Six of these instruments had been sent out to India some years before; they were modified in Bombay, so as to be similar to the new one which was tested at Chatham, and had scales of wheels put on for adaptation to particular tides, friction-rollers for the barrel, zero-lines for time and height cut, &c. As the rise and fall of the tide is materially influenced by direction and force of the wind, and also by changes in the barometer, self-registering anemometers and barometers were procured for each tidal station. On my return to India I was ordered to make a reconnaissance of the Gulf of Cutch, to select sites for tidal stations. I cruised about for a month in a common native sailing boat, and after long searching along the muddy foreshores of the Gulf I found three places well adapted for tidal observations—one right at the head of the Gulf, just in the Runn of Cutch, called Haustal Tidal Station, another midway up the Gulf of the Cutch coast, called Nowanar, and the third, Okha, just at the mouth of the Gulf, opposite the island of Beyt. They were well situated for the purposes required, as far as their geographical position, but as one was at a point twenty miles from the nearest village (from which drinking-water had to be brought by boat as well as food for the men in charge), another station nine miles, and the third two miles from the villages, the arrangements for the continuous working of the stations for about a year and a half had to be most carefully made. I returned to Bombay and got all the apparatus ready, such as iron cylinders in length (so as to be portable), iron piping, suction-piping, anchors and buoys, &c. for the deep-sea connexion, temporary tide-gauges for comparison, portable observatories—in fact every thing, even to bricks and lime for sinking the masonry well for holding the cylinders, for nothing could be procured in the places selected for the stations. While in Bombay I tested the working of the whole apparatus for each observatory, and made many modifications from time to time. I found that air would collect in the pipes, which were in the shape of a long siphon, and thus cause differences of level in the cylinder and the sea. I overcame this difficulty by inserting stopcocks at the top bends, which were to be always below the lowest high-water, and in this way I was able to get the same level of the water inside the cylinder as in the open sea. By frequent comparison with the temporary tide-gauges, the identity of level was determined; the size of the pipe connecting the cylinder had been calculated, so that practically there would be no retardation in the flow of the water. The native sub-surveyors, who were to be in charge of the stations, were also trained in Bombay.

The observations and apparatus were then described at length, and several illustrations and diagrams showed the method of their working. In addition to the self-registering anemometer and self-registering aneroid barometer, each observatory was fitted out with a standard mercurial barometer (for comparisons) and a rain-gauge. Three bench mark-stones in masonry platforms, at different distances from the observatory, were built as standard points for the levels, and each carefully connected with the zero of the self-registering tide-gauge. The whole of the apparatus and instruments were sent off in a large native sailing-vessel direct to Okha, the natives who were to be employed also going. I marched across Kattyawar to Okha, having made some arrangements with the Political Agent at Rajkot as to the help we should get from the native states. The construction of Okha tidal station was then described, and many of the difficulties which were successfully overcome, also the different methods of comparing position of pencil on diagram with the height of water, checks on the working of the instruments for insertion in the daily reports submitted by the sub-surveyors. I detected a serious fault in the self-registering tide-gauge, viz. that the instrument was by no means correct in the time registration. I eventually devised a simple plan, which I called "back-lash weight," which completely removed this cause of error. I am of opinion this plan ought to be carried out in its entirety, and the barrel made to drive the clock instead of the clock the barrel.

Just after all was ready, and the instruments being started at Okha, a great disaster happened early one morning. A boat drifted down past the station, her anchor dragged across the flexible pipe, smashed it, and carried off a large portion of it, as well as buoys, anchor, &c. Here we had to land and to have the repairs quickly executed, then the final measurements for determination of zero, rating of clocks, &c. were made, and the instruments started on their eighteen months' work. Leaving Okha, the vessel in which I and my men and all the apparatus were in ran straight on to a sandbank and nearly capsized. After many troubles, the other two stations were eventually constructed. Huts had to be made for the men in charge and the guard from the native state to live in, a regular service for sending food and water established, and post-runners started to carry the daily reports to the nearest post-office, and many other details arranged. I or my European assistant had to make frequent tours of inspection of the stations while work was going on, which entailed much hard marching and exposure. One journey (in May 1874) was described in which I and my assistant had to ride on camels over about fourteen miles of the Runn, covered with water from 6 inches to a foot deep, in order to reach Haustal Tidal Station. The working of the stations was then described, Okha and Haustal giving perfect and continuous registration, but at Nowanar, where there was 20 feet of water at the end of the pipe at low-water in April 1874, in the following July it silted up and buried the pipe, and the whole configuration of the foreshore altered. New pipes had to be got up, and two lunations (from March to May 1875) were secured, in addition to the one and half lunation got before the shore had altered in 1874. The registrations of the anemograph and barograph were continuous also. The levelling operations (750 miles of double levelling were done in connexion with the work) were next noticed, the rigid method of procedure which obtains in the Great Trigonometrical Survey of India, and which give such wonderfully accurate results, was referred to (*vide* Col. Walker's paper in vol. xxxiii. of the Memoirs of the Astron. Society).

The reductions of the tidal observations are in progress, some idea of the magnitude of which may be imagined when 30,000 points have been corrected to true mean local time on the diagram sheets, corrections made for zero error, and then the 30,000 final measurements made and tabulated for reduction. The determination of the mean level of the sea at each station and some of the results already deduced are stated: one is important, and that is, that the mean level deduced from the two months (March 7 to May 7) is nearly identical with the mean of the whole year, and this Col. Walker had predicted would be the case in a letter on the subject about eight years before. The meteorological reductions are in progress. The movement of the wind for each hour for the whole period has been tabulated and reduced to its N. and E. components, the mean hourly value determined, and, by combining the differences of this mean from the value of each particular hour, and similarly the barometric differences with the differences of the theoretical and actual values of the tide, I hope to determine far more accurately than has yet been done the effect of the wind and barometer on the tide. Several tracings of the actual diagrams were exhibited. The tidal curves are most regular and continuous, and show the perfect working of the whole apparatus, and when the tidal and meteorological reductions are complete, I hope to obtain some very valuable results.

Physical Explanation of the Mackerel Sky.

By Sir W. Thomson, *D.C.L., F.R.S.*

On Navigational Deep-sea Soundings in a Ship moving at High Speed.

By Sir W. Thomson, *D.C.L., F.R.S.*

CHEMISTRY

Address by WILLIAM HENRY PERKIN, *F.R.S., President of the Section.*

THERE can be no doubt that chemistry and the allied sciences are now being recognized to a much greater extent in this country than in former years, and not only so, the workers at research, though still small in number, are more numerous than they were.

In 1868 Dr. Frankland, in his Address to this Section at the Meeting at Norwich, commented upon the small amount of original research then being carried on in the United Kingdom; but, judging from the statistics of the Chemical Society, this state of things became even worse; for in 1868 there were forty-eight papers read before the Society, but in 1872 only twenty-two. Since then, however, there has been a considerable increase in the number; and at the Anniversary Meeting in March last it was shown that the number of communications for the session had risen to sixty-six, or three times as many as in 1872.

Of course these figures only refer to the Chemical Society; but I think they may be taken as a very fair criterion of the improved state of things, though it would be very gratifying to see much greater activity.

It is also very pleasing to find that the aids to and opportunities for research are increasing; because it must be remembered that, in a pecuniary sense, science is far from being its own rewarder at the time its truths are being studied, although the results very often become eventually of the greatest practical value, hence the wisdom of a country encouraging scientific research.

But little, however, has been done in this direction in past years—the grants made for general science by this Association and that of the Government of one thousand pounds annually to the Royal Society, being the most important.

The Chemical Society has also been in the habit of giving small grants for the purpose of assisting those engaged in chemical research. In the future, however, it will be able to do much more than hitherto. One of the original members of the Society, Dr. Longstaff, offered in the early part of the year to give one thousand pounds provided a similar sum could be raised, the united amount to be invested and the interest applied for the encouragement of research. I am happy to say that rather more than the required sum has been raised, and it is hoped that it may be still further supplemented.

In addition to the Royal-Society grant, the Government have given this year a further annual sum of four thousand pounds. Of course this is for science generally.

Mr. T. J. Phillips Jodrell has also placed at the disposal of the Royal Society the munificent sum of six thousand pounds to be applied in any manner that they may consider for the time being most conducive to the encouragement of research in Physical sciences.

When we consider how much of our science is of a physical nature, we must be grateful for this bequest; and it is to be hoped that these helps will more and more stimulate research in the United Kingdom, and if we have any hope of keeping pace with the large amount of work now being carried on in other countries, we must indeed be energetic.

The employment of well-trained chemists in chemical works is now becoming much more general than heretofore, especially on the continent, where in some cases a considerable staff is employed and provided with suitable appliances, &c., for the purpose not only of attending to and perfecting the ordinary operations which are in use, but to make investigations in relation to the class of manufacture they are engaged in. A conviction of the necessity of this is gaining strength in this country, though not so quickly as might be desired, nevertheless these things are encouraging.

With reference to the progress of chemistry and what have been the fruits of research of late years, it will be impossible for me to give even a general outline, the amount of work being so large, in fact, to recount the list of investigations made during the past year would take up most of the time at my disposal.

Amongst the most interesting, perhaps, are those relating to isomerism, especially in the aromatic series of organic bodies, and it is probable that a more intimate knowledge of this subject will be found of really practical value

As I am unable to give an account of the work done during the past year on account of its quantity and diversity I propose to refer to some of the practical results which have already accrued from Organic Chemistry as a plea for the encouragement of research, and those I intend to speak of are of special interest also on account of their close connexion with the textile manufactures of Great Britain I need scarcely say I refer to the colouring-matters which have been obtained from the products found in tar

It was in 1856, now twenty years since, that this industry was commenced by the discovery of the "mauve or 'aniline purple, and it may be of interest to state that it was in Scotland, in the autumn of the same year, that the first experiments upon the application of this dye to the arts of dyeing and calico printing were made, at Perth and Maryhill

I need scarcely remind you of the wonderful development of this industry since then, seeing we now have from the same source colouring matters capable of producing not only all the colours of the rainbow, but their combinations I wish, however, to briefly refer to the date and origin of the products which have served to build up this great industry

It was in 1825 that Faraday published in the 'Philosophical Transactions his research on the oily products separated in compressing oil-gas, and described a substance he obtained from it—a volatile colourless oil, which he called Bicarburetted Hydrogen Mitscherlich some years afterwards obtained the same substance from benzoic acid, and gave it the name it bears, viz 'Benzol This same chemist further obtained from benzol nitrobenzol, by acting upon it with nitric acid Zinin afterwards studied the action of reducing agents upon nitrobenzol, and obtained "aniline, which he at that time called Benzidam

Again, Pelletier and Walter discovered the hydrocarbon toluol in 1837 Deville produced its nitro-compound in 1841 and Hofmann and Muspratt obtained from this "toluidine, by the process used by Zinin to reduce nitrobenzol

I might mention other names in connexion with these substances, such as Runge and Unverdorben, but I would now ask, did any of these chemists make these investigations with the hope of gain? was it not rather from the love of research, and that alone? and now these products, which were then practically useless, are the basis of the aniline colours But to go further Doebereiner a long while ago obtained from alcohol a substance which he called "light oxygen ether," now known as aldehyd Gay-Lussac produced iodide of ethyl in 1815 Dumas and Peligot discovered the corresponding substance iodide of methyl in 1835, but, as in the cases I have previously referred to, these bodies had no practical value and were never prepared but in the laboratory Hofmann, in his researches on the molecular constitution of the volatile organic bases, discovered in 1850 the replacement compounds of aniline containing alcohol radicals

All these compounds have now been manufactured on the large scale and used in the further development of the industry of these artificial colouring-matters

Other substances might be mentioned, but I think these are sufficient to show how the products of research which, when first discovered and for a long period afterwards, were of only scientific interest, at last became of great practical value, and it is evident that, had not the investigations and discoveries I have referred to been made as they were solely from a love of science, no aniline colours would now be known

The colouring-matters I have hitherto spoken of are nitrogenous, and derived from benzol and its homologues There are a few others, however, of the same origin which contain no nitrogen, but they are of secondary importance

I now pass on to another class of colouring-matter, which is obtained from anthracene, a coal-tar product differing from benzol and toluol in physical characters, inasmuch as it is a magnificent crystalline solid

The first colouring-matter derived from anthracene which I wish to draw your attention to is alizarin, the principal dyeing agent found in madder-root. This substance was for a long time supposed to be related to naphthaline, inasmuch as phthalic acid can be produced from both of them, and many were the experiments made by chemists in this direction; it was not, however, until 1868 that this was proved to be a mistake, and its relationship to anthracene was discovered by Graebe and Liebermann, who succeeded in preparing this coal-tar product from the natural alizarin itself.

Having obtained this important result they turned their attention further to the subject, hoping to find some process by which alizarin could be produced from anthracene; in this they were soon successful.

The discovery of the artificial formation of alizarin was of great interest, inasmuch as it was another of those instances which have of late years become so numerous, namely the formation of a vegetable product artificially; but the process used by Graebe and Liebermann was of little practical value, because too expensive for practical purposes.

Having previously worked on anthracene derivatives, it occurred to me to make some experiments on this subject, which resulted in the discovery of a process by which the colouring matter could be economically produced on the large scale. Messrs. Caro, Graebe and Liebermann about the same time obtained similar results in Germany; this was in 1869. Further investigation during that year yielded me a new process, by which dichloranthracene could be used in place of the more costly product anthraquinone which was required by the original processes. I mention this, as most of the artificial alizarin used in this country up to the end of 1873, and a good deal since, has been prepared by this new process.

It was observed that when commercial artificial alizarin prepared from anthraquinone, but more especially from dichloranthracene, was used for dyeing, the colours produced differed from those dyed with madder or pure alizarin; and many persons therefore concluded that the artificial colouring matter was not alizarin at all. This question, however, was set at rest by separating out the pure artificial alizarin from the commercial product and comparing it with the natural alizarin, when it was found to produce exactly the same colours on mordanted fabrics, to have the same composition, to give the same reactions with reagents, and to yield the same products on oxidation.

But whilst examining into this subject it was found that a second colouring-matter was present in the commercial product, and in somewhat large quantities, especially when dichloranthracene had been employed in its preparation; and to this was due the difference in shade of colour referred to.

This substance, when investigated, was found to have the same composition as "purpurin," also a colouring-matter found in madder, but of very little value on account of the looseness and dulness of some of the colours it produces. This new substance, being derived from anthracene, was named anthrapurpurin; unlike its isomer purpurin, however, it is of great value as a colouring-matter. I do not think I shall be going beyond the results of experience if I say it is of as great importance as alizarin itself; with alumina mordants it produces reds of a more scarlet or fiery red than those from alizarin. In fact so fine are the colours produced that, with ordinary alumina-mordants on unoiled cotton, it gives results nearly equal in brilliancy to Turkey-red produced with madder or garancine; and I believe the rapid success of artificial alizarin was greatly due to its presence. Most of that consumed at first was for Turkey-red dyeing, and the colours were so clear that it was mostly used in combination with madder or garancine, to brighten up the colours produced by these natural products.

The purple colours anthrapurpurin produces with iron mordants are bluer in shade than those of alizarin, and the blacks are very intense. Its application is practically the same as alizarin, so that they can be used in combination.

As already noticed, the commercial product called "artificial alizarin" first supplied to the consumer was always a mixture of alizarin and anthrapurpurin, and various mixtures of these two colouring-matters are still sent into the market; but, owing to the investigations that have been made and the study and attention that has been given to it by manufacturers, nearly pure alizarin and anthrapurpurin are also sent into the market—the first being known as "blue-shade alizarin," and the second as red or "scarlet alizarin."

The formation of anthrapurpurin in the manufacture of alizarin may to some extent be said to have arisen from a want of knowledge of the true conditions required for the production of the latter.

It is now well known that alizarin is a dioxyanthraquinone, or, in other words, anthraquinone in which two atoms of hydrogen are replaced by hydroxyl.

$$\underbrace{C_{14}H_8O_2}_{\text{Anthraquinone}} \qquad \underbrace{C_{14}H_6(HO)_2O_2}_{\text{Alizarin}}$$

If we want to introduce hydroxyl into a compound there are several processes which can be used, but I will only refer to those connected with the history of this colouring matter.

The first process which I will refer to has been used by chemists for a long period. It consists in first replacing the hydrogen by bromine and then treating the resulting body with potassic or other metallic hydrate: and according as one, two, or more atoms of hydrogen have been replaced by the bromine, so on its removal by the metal of the metallic hydrate a compound containing a corresponding number of atoms of hydrogen replaced by hydroxyl is obtained.

Graebe and Liebermann acted upon this principle in their experiments on the artificial formation of alizarin: and as it was necessary to replace two atoms of hydrogen in anthraquinone, they first of all prepared a dibrominated derivative, called dibromanthraquinone,

$$C_{14}H_6Br_2O_2.$$

By decomposing this with potassic hydrate at a high temperature they obtained a violet-coloured product, which when acidified to remove the alkali gave a yellow precipitate of alizarin,

$$C_{14}H_6(HO)_2O_2.$$

The second process I wish to speak of for the replacement of hydrogen by hydroxyl in a compound is by converting it into a sulpho acid (usually by means of sulphuric acid) and subsequently decomposing this with potassic or other hydrate: and according as a mono or disulpho acid is employed it yields on decomposition a compound with one or two atoms of hydrogen replaced by hydroxyl.

The discovery of sulpho-acids of anthraquinone, and their use in place of the brominated derivative originally employed by Graebe and Liebermann, constituted the great improvement in the manufacture of alizarin already referred to.

From what has just been stated, it was naturally supposed that a disulpho-acid of anthraquinone would be required to produce alizarin: and this was believed to be the case for some time; but further experiments have proved it to be a mistake, and shown that the monosulpho acid is required to produce alizarin, the disulpho-acid yielding anthrapurpurin.

But how are we to explain this apparent anomaly? It would take up too much time to enter into a discussion respecting the constitution of the sulpho-acids of anthraquinone in reference to the position of the HSO_3 groups. I will therefore confine my remarks to their decomposition.

Monosulphoanthraquinonic acid,

$$C_{14}H_7(HSO_3)O_2,$$

when heated strongly with caustic alkali, as potassic or sodic hydrate, decomposes in the ordinary way, and we get "monoxyanthraquinone,"

$$C_{14}H_7(HO)O_2,$$

which is a yellow body possessing no dyeing properties. On further treating this, however, with caustic alkali it changes, being oxidized, and yields alizarin,

$$C_{14}H_6(HO)_2O_2.$$

Disulphoanthraquinonic acid,

$$C_{14}H_6(HSO_3)O_2,$$

when subjected to the influence of caustic alkali, at first changes into an intermediate acid,

$$C_{14}H_6(HO)(HSO_3)O_2,$$

and then into a dioxyanthraquinone,

$$C_{14}H_6(HO)_2O_2,$$

now known as "isoanthraflavic acid"—a substance having the same composition as alizarin, but being only an isomer of that body and possessing no affinity for mordants, like monoxyanthraquinone, however, when further heated with alkali it becomes oxidized and yields a colouring-matter, which is "anthrapurpurin,

$$C_{14}H_5(HO)_3O_2$$

Looking at these reactions, it appears rather remarkable that Graebe and Liebermann should have succeeded in preparing alizarin from dibromanthraquinone It can only be explained on the assumption that the hydrogen atoms replaced in the disulpho-acid are different in position from those replaced in the dibromanthraquinone, and of course it is possible that a disulpho acid isomeric with that now known may be discovered that will yield alizarin as a first product on treatment with alkali

In the reaction which takes place when monoxyanthraquinone or isoanthraflavic acid become oxidized and change into alizarin and anthrapurpurin nascent hydrogen is formed, and this causes a reverse action to take place—ordinary anthraquinone, or its hydrogen derivative being formed, and a loss of colouring matter resulting A small amount of potassic chlorate is now used with the caustic alkali, just sufficient to overcome the reducing action, which has resulted in an increased yield of colouring-matter, the percentage obtained being now not very much below the theoretical quantity

When the process for making commercial artificial alizarin by treating anthraquinone with sulphuric acid was first adopted, the product from that treatment was a mixture of the mono and disulpho-acids of anthraquinone Consequently the colouring-matter prepared in this manner was a mixture of alizarin and anthrapurpurin, and the reason why dichloranthracene, when used in place of anthraquinone, yields a product very rich in anthrapurpurin, is on account of the readiness with which it forms a disulpho acid of dichloranthracene, which afterwards changes into the disulpho acid of anthraquinone

At first it was supposed by many that the quantity of coal-tar produced would not yield a sufficient supply of anthracene for the manufacture of artificial alizarin Experience has, however, proved that this supposition was groundless, as now the supply is greater than the demand

Moreover some very interesting experiments have lately been made, by which anthraquinone and its derivatives have been obtained without the use of anthracene The most interesting are those in which phthalic anhydride is employed with benzolic derivatives, for example, this anhydride gives with hydroquinone a colouring-matter having the same composition, as well as most of the other properties of alizarin It is called quinizarin Baeyer and Caro have also obtained from phthalic anhydride and phenol oxyanthraquinone, and by using pyrocatechin in place of phenol they got alizarin itself

Although these products have not been obtained in sufficient quantities by these processes to be of any practical value, we do not know what further research may do Already one of the substances used is being prepared on the large scale for the manufacture of that beautiful colouring-matter "eosine," I refer to phthalic anhydride

Now, with reference to the origin of the products which are used for the manufacture of artificial alizarin, we find the first researches made in reference to anthracene were by Dumas and Laurent in 1832, subsequently Laurent further worked upon this subject, and obtained, by the oxidation of this hydrocarbon, a substance which he called anthracenuse, he also obtained dichloranthracene Dr Anderson also made an investigation on anthracene and its compounds in 1863, and assigned to it its correct formula, he reexamined its oxidation-product, which Laurent called anthracenuse, and named it oxyanthracene, the substance we now know as anthraquinone

All these substances were without any practical value until 1868, but we now find them of the greatest importance, and used daily in immense quantities

But to bring out more clearly the practical importance of these fruits of scientific research, it will be well perhaps to see what has been their influence on the colouring-matters which were in use before them, and also the extent of their present consumption.

The influence of the so-called aniline colours on dye woods, &c. has been remarkably small. It is true that at first magenta had a depreciating influence upon cochineal, but this has passed away, and now the consumption of that dye is as great as ever; certainly its price is much lower than it used to be, but this is due to a variety of causes, especially the great increase in the cultivation of the insect at Teneriffe. And perhaps this want of influence is not so very remarkable, when we consider the aniline colours are entirely new products, differing in composition and properties from the old colouring matters, and therefore could only displace them to a certain extent.

But whilst this is the case, the aniline colours have been more and more used, until at present it is computed that their annual sale in the United Kingdom and on the Continent exceeds £2,000,000. This is probably due to new applications and increase of trade.

When, however, we come to consider the influence of the anthracene colours alizarin and anthrapurpurin, more generally known as 'artificial alizarin,' we find we have a very different tale to tell.

Here, in the case of alizarin, we have a competition not between two colouring-matters, but the same from different sources—the old source being the madder-root, the new one coal tar. And when we introduce the consideration of anthrapurpurin, which produces such magnificent reds much brighter than those of ordinary purpurin, we see we have not only a replacement but an improvement, so that these new colouring matters throw the old ones into the shade. The products being purer, the clearing processes for goods dyed with them are also necessarily easier and simpler.

It will be interesting to examine into the statistics of the madder and garancin trade in a brief manner, to see what has been the influence of artificial alizarin on their consumption. The following figures are mostly calculated from the Board-of-Trade returns.

During the ten years immediately preceding the introduction of artificial alizarin the average annual imports of madder into the United Kingdom were 15,292 tons, and of garancin 2278 tons. Estimating the value of the former at £2 2s. 6d., and the latter at £8 per cwt., which were about the average prices during that period, the annual value in round numbers was about one million sterling.

The introduction of artificial alizarin, however, has so influenced the value of madder that its price is now less than one half, and thus a saving of over half a million sterling per annum has been effected to the manufacturers of the United Kingdom, one half of which may be put down to Glasgow.

So much for its effect in reducing prices; but what has been its influence on the consumption of these dye-stuffs?

I have already stated the average quantity of these substances imported per annum prior to the discovery of the artificial product, and will now compare it with the imports of last year and this. That for the present year of course will be an estimated quantity, and calculated from the returns for the first seven months.

	Average annual imports		
	1859–1868	1875	1876
	tons	tons	tons
Madder	15,292	5014	3653
Garancin	2,278	1293	813

These figures speak for themselves.

The money value, which was formerly £1,000,000 per annum, is now, calculating from the estimated quantity for the year, only £138,105, say £140,000, taking garancin at £4 per cwt. and madder at £1 per cwt., prices slightly in excess of their present value.

At the present prices the cultivation of madder-roots is unremunerative, and it is to be expected that madder-growing will soon be a thing of the past, thousands of acres of land being at the same time liberated for the growth of those products we cannot produce artificially, and without which we cannot exist. The quantity of madder grown in all the madder-growing countries of the world prior to 1868 was estimated to be 70,000 tons per annum, and at the present time the artificial colour is manufactured to an extent equivalent to 50,000 tons, or more than two thirds of the quantity grown when its cultivation had reached its highest point.

I might have referred to other subjects besides the coal tar colours which have resulted from scientific research, but I know of no other of such interest and magnitude. From the brief history I have given, we see that the origin of these colouring-matters is entirely the fruit of many researches made quite independently by different chemists who worked at them without any knowledge of their future importance, and on looking at the researches which have thus culminated in this industry it is interesting to notice that many, if not most of them, were conducted for the purpose of elucidating some theoretical point.

These facts certainly ought to be a great encouragement to chemists, and stimulate them to greater activity. It would be very pleasing to see more work emanating from the chemical schools of the United Kingdom; and I think no student should consider his chemical curriculum finished until he has conducted an original research. The knowledge obtained by a general course of instruction is of course of very great value; but a good deal of it is carried on by rule. In research, however, we have to depend upon the exercise of our judgment, and in fact of all our faculties; and a student having conducted even one under the guidance of an efficient director, will find that he has acquired an amount of experience and knowledge which will be of the greatest value to him afterwards.

It is hoped these remarks will encourage young chemists to patiently and earnestly work at whatever subject they may undertake, knowing that their results, although sometimes apparently only of small interest, may contain the germ of something of great scientific or practical importance, or may, like a keystone in an arch, complete some subject which before was fragmentary and useless.

On a Safe and Rapid Evaporating-pan. *By* F. H. T. ALLAN.

In the course of various chemical manufactures there is sometimes met the difficulty of products and apparatus being injured or destroyed in the process of rapid evaporation by the salts settling to the bottom of the pan, and there becoming a solid mass. This pan is intended as an effort to overcome that difficulty.

Besides attempting to compass the evaporation of the leys or other fluids *safe* from the danger of deposition upon the heating surface, it also provides for the *rapid* evaporation of the fluids, with *continuous* action in the pan, and the *ready removal* of the solids when formed. To attain these several ends, the form to be described has been found necessary. The pan may be made of boiler-plate, and about 30 feet long, by 10 feet broad, and 9 feet high. The heating surface is supplied by two flues of a V-shape carried through the fluid from one end of the pan to the other. The acutest angle of the V is downward, and within 2 feet of the bottom of the pan. This form of heat-source whilst raising the temperature to boiling-point and effectually keeping it there, offers no resting place for descending particles, and consequently the salts on separating fall to the bottom of the pan and there accumulate. Now the apparatus is so arranged that the bottom slopes in one or more directions, the salts gather in the deepest parts, and suitable outlets that may be closed at pleasure being provided in the sides, they gravitate outwards into proper receptacles. Care must be taken that sufficient solids are left in to occupy the outlets, and the passage of fluids thereby prevented.

The upper part of the V-shaped flue is covered in its whole length and breadth by an air-chamber of iron fitted with pipes or other arrangement passing into the liquid, whereby the air heated from the waste heat of the flue is forced into the boiling liquid, and there materially increases the rapidity of the evaporation.

For the purpose of utilizing any heat that may escape from the air-chamber a small pan occupies its upper surface. On this subsidiary pan the liquid may be boiled to nearly salting-point, and then allowed to flow into the salting-down pan, the smaller one being replenished with weak liquor A limited supply of air may be introduced into the second pan, and evaporation proceeds very rapidly

The liquor in the pans need never lose its level, because, as salts pass from below and steam from above continuously, it is continuously replaced by liquor flowing in, the air-pipes may therefore be only two or three inches below the surface of the fluid The pressure thus being not great, an ordinary fan will be sufficient to force the air through for evaporation

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On Sewage Purification and Utilization By J BANKS

On a new Voltaic Battery By H W BIGGS

On the Action of Pentachloride of Phosphorus on Turpentine
By Prof CRUM BROWN

Note on Anthracene testing By JAS T BROWN

In the earlier days of anthracene manufacture, when it was obtained solely from the last runnings of oil, and when the distillation was stopped comparatively early for the double reason of saving the bottoms of the stills and producing a good marketable pitch the principal solid impurities were naphthalene, phenanthrene, and paraffin With samples of this description the method of testing by agitation, after washing with petroleum spirit with a limited quantity of bisulphide of carbon gives approximate and practically useful results When however the demand for anthracene increased, the tar-distillers found it more advantageous to carry on the distillation as far as possible only stopping just before the point at which coking commenced This method of working gives an entirely different variety of crude anthracene, viz one in which the principal solid impurities have higher boiling points than anthracene These bisulphide of carbon fails to remove, that test therefore, with these samples, ceases to give true indications of their commercial value To correct this the anthrakinone test was introduced and was judging from the terms in which it was proposed, looked upon as applicable to *all* commercial anthracenes The appendix to the paper soon followed and showed that experience had not confirmed those anticipations, and now the kinone produced requires to be tested as to its purity, as the result is by no means definite In applying the kinone test to commercial samples various minor difficulties occur, one of which is that damp samples of anthracene are apt to lose moisture during the time that is occupied in reducing them to a sufficient degree of fineness to allow the small quantity of 1 gramme to be a correct sample of the bulk, and another and more serious one is the uncertainty caused by the occasional occurrence of accidental impurities in the quantity weighed out To remedy these defects and facilitate the testing, the author proposes the following modification —

Weigh out 50 grammes of the crude anthracene, and measure out 250 cubic centims of petroleum spirit, triturate the anthracene in a mortar with a sufficient quantity of the spirit to form a thin cream, and pour it on a weighed filter (taking care at the same time to leave in the mortar any grit or sand which may be present); rinse on to the filter any anthracene which may be round the sides of the mortar, and employ the remainder of the spirit in washing the filter and its contents. Allow it to drain, then fold it carefully, press between bibulous paper, dry at about 60°–80° C, and weigh Crush to a fine powder the contents of the filter, and from that quantity weigh out the gramme required for the kinone test, then proceed in the usual manner In calculating the result allowance must of course be made for the diminution in weight caused by washing the crude sample with petroleum spirit.

The method proposed in the foregoing short note does not claim for itself theoretical accuracy, but it claims the following advantages —

1st. It affords a ready method of detecting and separating extraneous matter, such as grit, sand, shreds of canvas, or splinters of wood, all of which are liable to occur even in good anthracene.

2nd. The preliminary washing produces a dry powder of perfect uniformity, from which it is easy to weigh out a small quantity.

3rd. The preliminary washing removes, beside others, the greater part of two important impurities, one of which, viz. paraffin, defies the kinone test, and the other, viz phenanthrene, is not, if present in large quantities, completely oxidized under a considerable time.

4th. By removing a large proportion of the impurity beforehand the oxidation proceeds more quietly, and the kinone obtained is more crystalline and freer from chromium compounds.

On some Instruments used in the 'Challenger.' *By* J. Y. BUCHANAN.

On Ammonic Seleniocyanide. *By* Dr. CAMERON.

On a Gas-condensing Machine for the Liquefaction of Gases by combined cold and pressure, recently employed in the manufacture of Volatile Liquid Hydrocarbons. *By* J. S. COLEMAN, *F C.S.*

This paper gives a *résumé* of the author's paper on the effects of pressure and cold upon the gaseous products of the distillation of shales, read to the Chemical Society, September 1875.

It then enters into certain thermodynamical questions relating to the best method of obtaining cold from a compressed gas, so as to utilize the cold produced in expansion, to supplement the effect produced by simple pressure

It then describes the engineering arrangements finally adopted for dealing with 250,000 feet of gas daily at the works of Messrs Young & Co, on the principle of the drawing exhibited The diagrams used were enlargements of the actual drawings of the machine as erected, and showed all the precautions found necessary in actual construction. The working of the machine, which gives, as a maximum, 2000 gallons per week, during the last three months was described, and samples of the product exhibited burning in Laidlaw's air-gas apparatus.

Experimental Researches on the Chemical Treatment of Town Excretion. *By* J. S. COLEMAN, *F C.S.*

On the Transformation of Chinoline into Aniline. *By* Prof. DEWAR, *F.R.S.E.*

On the Proximate Analysis of Coal-Gas.—Remarks on Reboul's Paper on Pyro-Tartaric Acid *By* W. DITTMAR.

On an Apparatus for the Analysis of Impurities in the Atmosphere. *By* E. M. DIXON.

On Fire-Brick. *By* J. DUNNACHIE.

On White-Lead. *By* A. FERGUSSON.

On the Physiological Action of Pyro-, Meta-, and Ortho-phosphoric Acids.
By Prof. GAMGEE, *F.R.S.*

On the Influence of the Condition and Quantity of the Negative Element on the Action of the Copper-Zinc Couple.
By Professor GLADSTONE, *F.R.S.*

On Solid Water.
By Prof. GUTHRIE, *F.R.S.*

On the Critical Point of Liquid Carbonic Acid in Minerals.
By W. N. HARTLEY.

The History of Copper-extraction by the Wet Way.
By WILLIAM HENDERSON.

In this paper the author related the history of the introduction of these processes and their establishment in this country and abroad; he described the various stages of the manufacture of Spanish cupreous pyrites by his processes; he also described and illustrated by specimens the recent modifications introduced for improving the quality of the copper, and at the same time separating the small quantity of lead, silver, and gold always present in Spanish pyrites.

On the Purification of the Clyde.
By Col. HOPE, *V.C.*

On the Limited Oxidation of Terpenes.—Part IV.*
By CHARLES T. KINGZETT, *F.C.S.*

In this part of his researches the author has more particularly inquired into the phenomena attendant upon the atmospheric oxidation of turpentine in the presence of water. These phenomena may be stated as:—

(*a*) Increase of the specific gravity of the oil as the oxidation proceeds.

(*b*) Gradual increase in the amount of peroxide of hydrogen produced, or the rate at which it forms.

(*c*) Gradual heightening of the boiling-point of the oil as it oxidizes.

The oxidation, which takes place slowly at first, proceeds very actively afterwards, and the oil thus under treatment is capable of inducing fresh turpentine, which may be added, to undergo oxidation at the same rate from the moment of contact.

The oxidized oil evolves large quantities of oxygen on heating to near 160° C., and this oxygen is doubtless derived from camphoric peroxide. To the same substance the author assumes to be due the camphoric acid and peroxide of hydrogen found in the aqueous solution that results from its decomposition with water.

There are contained also in the watery solution obtained when turpentine is atmospherically oxidized in the presence of water, acetic acid, camphor, &c. Thus a solution obtained in one experiment upon several gallons of turpentine contained 323 grains of peroxide of hydrogen and 307 grains of camphoric and acetic acids. The amount of peroxide of hydrogen produced is simply limited by the amount of turpentine oxidized, and can be regulated at will.

This aqueous solution the author has proved to possess most powerful characters as an antiseptic and disinfectant, and continued investigations have shown these characters to be possessed by the individual constituents of the solution, viz. camphoric acid, peroxide of hydrogen, &c. In the last part of his research the author has resumed the thread of his researches previously published, and found that menthene ($C_{10}H_{18}$), whether derived from solid or liquid Japan camphor (by the action of $ZnCl_2$), produces, on atmospheric oxidation, among other bodies peroxide of hydrogen, acetic and formic acids, &c Now Wright (Journ. Chem Soc. ser. 2, vol xiv p. 2) has obtained from menthene, by the action of bromine, cymene, and so the conclusion stated in the author's previous papers that all hydrocarbons containing cymene as a proximate nucleus give peroxide of hydrogen on oxidation is confirmed.

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* Printed *in extenso* in Chem. News, vol. xxxiv. pp. 127 & 135, and in Pharm. Journ. Sept. 23, 1876.

Wright has also failed to obtain cymene ($C_{10}H_{14}$) from clove terpene ($C_{15}H_{24}$), a result in accordance with the author's observations previously made to the same effect.

The author has submitted the ethers also to atmospheric oxidation, and in this way results have been obtained which are of the greatest interest and importance. Ethylic ether $\left.\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right\}O$ absorbs oxygen even in the cold, but more readily in sunshine, and gives rise in the presence of water to peroxide of hydrogen, which may result from reactions represented by the following equations —

$$(1)\qquad \left.\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right\}O+O_2=\left.\begin{matrix}C_2H_3O\\C_2H_5\end{matrix}\right\}O+H_2O,$$

$$(2)\qquad \left.\begin{matrix}C_2H_3O\\C_2H_5\end{matrix}\right\}O+O_3=\left.\begin{matrix}C_2H_3O\\C_2H_3O\end{matrix}\right\}O_2+H_2O,$$

$$(3)\qquad \left.\begin{matrix}C_2H_3O\\C_2H_3O\end{matrix}\right\}O_2+2H_2O=\left.\begin{matrix}C_2H_3O\\H\end{matrix}\right\}O+\left.\begin{matrix}C_2H_3O\\H\end{matrix}\right\}O+H_2O_2;$$

or (3) may be written thus:—

$$\left.\begin{matrix}CH_3COO\,O\\CH_3COO\,O\end{matrix}\right\}+\left.\begin{matrix}H\,HO\\H\,HO\end{matrix}\right\}=\left.\begin{matrix}CH_3COOH\\CH_3COOH\end{matrix}\right\}+\left.\begin{matrix}HO\\HO\end{matrix}\right\}$$

That is to say, the ether may, in the first place, become acetic ether and eliminate water; secondly, the acetic ether may become anhydride, and the latter may be finally converted into peroxide. This peroxide, being unstable in the presence of water, splits up into acetic acid and peroxide of hydrogen

These results are confirmed by the fact that Brodie discovered acetic peroxide by acting on acetic anhydride with baric dioxide

These equations are, moreover, exactly parallel with those indicated by the author as representing the production of hydric peroxide from turpentine, and it is to their substantiation that his efforts in the future will be directed. Meanwhile he claims that they experimentally demonstrate clearly for the first time the existence of the radical hydroxyl in combination, and, in short, the production of peroxide of hydrogen in the way described amounts to the isolation of hydroxyl in combination with itself.

On two new Hydrocarbons from Turpentine. *By* A. C. Letts.

On Soda Manufacture. *By* J. Mactear.

On the possible Genesis of the Chemical Elements out of a Homogeneous Cosmic Gas or Common Vapour of Matter *By* Dr. Macvicar, *F.R.S.E.*

On Essential Oil of Sage.—Part I.* *By* M. M. Pattison Muir, *F R S E.*

This oil has a yellow-brown colour, without any shade of green, a strong sage-like odour, and a hot burning taste. Its reaction is neutral. Sage-oil does not deposit

* Published in the Year-book of Pharmacy, 1876, p. 560

any solid matter nor resin after standing for some months exposed to air, neither does its reaction alter The oil rapidly absorbs oxygen from air It is most energetically acted upon by strong nitric acid also by sulphuric acid which appears to polymerize some of the constituents of the oil Hydrochloric acid gas produces one or perhaps two liquids but no solid chlorhydrates these are scarcely if at all, decomposed by prolonged agitatation with warm water The specific gravity of sage-oil is 0 9339 at 14° C After prolonged fractionation the oil splits up into four main portions—two liquids, almost certainly terpenes, boiling respectively at 157° and at 167° C , a liquid, probably containing oxygen boiling at 198° 203° and a solid camphor melting at 187° C The terpenes both appear to contain cymene as by treatment with sulphuric acid the liquid being carefully kept cold, and distillation in steam cymene is obtained These terpenes yield brominated compounds, which split up, on distillation into hydrobromic acid and cymene the brominated compound from the lower boiling terpene is much more stable however than that from the terpene of higher boiling point. For the oxygenized liquid constituent of the oil the name of *salviol* is proposed The terpenes both yield terephthalic acid on oxidation with weak chromic liquor

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On the action of Dilute Saline Solutions upon Lead[*]
By M M PATTISON MUIR, *F R S E*

After generalizing former results the author describes experiments carried out under varying conditions which seem to prove —

(1) That increase of surface of lead exposed is generally associated with increase of lead dissolved This conclusion does not, however, invariably hold good, the nature of the salt in solution, the time of action, &c influence the action

(2) That exposure of large surfaces of liquid to the surrounding air very generally causes an increase in the quantity of lead dissolved, this increase being most marked in the case of those salts (nitrates &c) which enable water to exercise a notable solvent action upon lead, and after the expiry of lengthened periods of time

(3) That the solvent action of dilute saline solutions upon lead increases in an ever-increasing ratio with increase of time of action (longest period tried = 505 hours), except in the case of potassium carbonate solutions, where a point of maximum action appears to be reached after the expiry of about 340 hours

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On certain Compounds of Bismuth[†] *By* M M PATTISON MUIR, *F R S E*

In this paper the following salts of bismuth are described —

Bismuthous trichloride and tribromide the action of hydrogen upon these salts is detailed Attempts to prepare a chloride higher than $BiCl$ which led to no positive results, are described *Ammonio bismuthous tribromides* $BiBr_3\ 3NH_3$, $BiBr_3\ 2NH_3$ and $2BiBr_3\ 5NH_3$, *bismuthyl oxybromides*, Bi_8Br_6O , and $Bi_{11}Br_7O_{13}$, *bismuthic bromo-nitride*, BiN_2Br *hypobismuthic hydrate*, $Bi_2O_4\ H_2O$, and a number of chromates of bismuth, the principal of which are —*bismuthyl chromate*, $(BiO)_2CrO_4$, *bismuthyl dichromate*, $(BiO)_2Cr_2O_7$, *monohydrated bismuthyl dichromate*, $(BiO)_2Cr_2O_7\ H_2O$, and *monohydrated bismuthyl tetrachromate*, $(BiO)_2Cr_4O_{11}\ H_2O$

On Relations among the Atomic Weights of the Elements
By J. A R NEWLANDS

On the Alum Process in Sugar-refining *By* J A R NEWLANDS

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[*] *Vide* Proc Manch Lit and Phil Soc 1876–77, pp 1 & 142

[†] Journ Chem Soc vol i 1876 p 144, vol. ii p 12, and vol i 1877, p 24

On Sugar. *By* T. L. PATTERSON.

Note on some new Anthracene Compounds. *By* W. H PERKIN, *F R.S.*

A very dilute solution of anthracene in carbon disulphide, when cooled to 0° C. and treated with bromine, yields an addition product, a "dibromide of anthracene," $C_{14}H_{10}Br_2$. It is a very unstable body, rapidly decomposing at the ordinary temperature of the air, with evolution of hydrobromic acid, when heated it also gives off this acid, and is converted into monobromanthracene, $C_{14}H_9Br$.

If chlorine be used in place of bromine, a "dichloride of anthracene," $C_{14}H_{10}Cl_2$, is produced, which is even less stable than the corresponding dibromide; when heated it decomposes and yields monochloranthracene, $C_{14}H_9Cl$.

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*On Picoline and its Derivatives**. *By* WILLIAM RAMSAY, *Ph.D.*

The following salts of picoline were prepared —

The *hydrochloride*, deliquescent, melting at 100° C

The *hydrobromide*, melting at 187°. These two salts may be crystallized from impure picoline.

The *dibromide of picoline hydrobromide* —Prepared by treating the hydrobromide with bromine. It forms golden-yellow scales, and melts at 85°. It is sparingly soluble in water

The *diiodide of picoline hydriodide* —Formed when picoline hydriodide is distilled. Reddish-brown crystals, which melt when brought in contact with water, soluble in alcohol and in ether. Melting-point 79°

The formula of Anderson's trichloropicoline hydrochloride is disputed, both from the results of analysis, from its method of preparation, and from its properties It appears to be a hypochlorite, and to contain the group (O Cl) The white powder to which Anderson ascribes the formula $C_6H_4Cl_3N.HCl$ is a product of the action of water on an oil obtained by projecting picoline into chlorine gas

Picoline dibromide, $C_6H_7N\,Br_2$, formed by the action of a solution of bromine in chloroform on picoline, and

Picoline iodochloride, $C_6H_7N.ClI$, prepared in a similar manner, are crystalline solids The halogens, therefore, act on picoline to form at least four distinct substances —1, a direct addition compound containing picoline plus two atoms of halogen, 2, a substitution compound which undergoes alteration when brought in contact with water, 3, a salt of the halogen acid, and 4, an addition-product containing two atoms of the halogen combined with the haloid salt.

The *ferrocyanide* forms white crystals.

The *platinocyanide* consists of large pale yellow rhomboids. It crystallizes with $4H_2O$.

The *tartrate* forms long white needles.

The *citrate* is uncrystallizable

The *phosphate* is a white deliquescent crystalline mass.

The *chlorate* forms very thin diamond-shaped crystals.

The following compounds with alcohol radicals were prepared :—

The *methyl iodide*, by mixing equivalent quantities of methyl iodide and picoline. Long white needles, which melt at 226° 5–227°.

The *methyl chloride* is an extremely deliquescent salt, and crystallizes from alcohol in needles.

The *methyl nitrate* forms large transparent prisms.

The *methyl hydrate*, prepared by means of moist silver oxide, rapidly becomes discoloured in the air, and when acted on, first with bromine, then with ammonia, assumes a red colour. No methylamine was evolved on boiling its aqueous solution.

The *diiodide of the methyl iodide*, $C_6H_7N(CH_3I)I_2$, crystallizes from alcohol in feathery bluish-black crystals. It is prepared by dissolving iodine in an alcoholic solution of the methyl iodide.

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* *Vide* Phil Mag 1876, vol. ii p 269.

The *ethyl iodide* is analogous to the methyl iodide, and the ethyl hydrate gives a similar reaction with bromine and ammonia.

The *ethene bromide* forms small hard prisms, which melt at about 276°. The ethene chloride crystallizes from alcohol in needles.

Picoline allyl compounds are all sirups, with exception of the platino-chloride. The hydrate is more stable than the methyl, ethyl, or ethene hydrates, and after evaporation at 100° dissolves in alcohol with a brilliant purple colour, which may be communicated to silk.

As picoline is not decomposed by potash in any form, it cannot be a nitrile or a carbonine. It is not altered by being passed through a red-hot tube filled with lime or lead peroxide. Boiling sulphuric acid and nitric acid or a mixture of both, have no action on picoline, but when the nitrate is heated it undergoes complete decomposition into carbonic acid and probably water.

Picoline probably does not contain a methyl group, for on oxidation it yields Dewar's pyridene dicarbonic acid. This acid is not derived from lutidine, as was supposed by Wright. Experiments to prepare the aldehyde and alcohol from dicarbo-pyridenic acid lead to a prospect of success, and from the alcohol true methyl pyridine may possibly be obtained.

On Glucinum, its Atomic Weight and Specific Heat.
By J. Emerson Reynolds, *M.D.*

On the Utilization of Sewage. *By* W. C. Sill

On the Action of Hydriodic Acid on mixed Ethers of the General Formula $C_nH_{2n+1}+O\ CH_3$.* *By* R. D. Silva.

On Sodium. *By* Anderson Smith.

On the Manufacture of Iodine.† *By* Edward C. C. Stanford, *F.C.S.*

The author gives an interesting account of this manufacture, which in Great Britain is confined to Glasgow and its neighbourhood. He gives a *résumé* of the remarkable fluctuations in the price of iodine, and also of the changes in the uses of kelp, or sea-weed ash, from its first manufacture about a hundred years ago to the present time. He traces its use from the beginning of the present century, when it was the principal source of alkali, and when Scotland alone produced 20,000 tons annually, worth £20 to £22 per ton. During the following 22 years the importation of barilla reduced the price of kelp to £10 per ton. Then the removal of the duty on barilla, followed by that on salt, reduced it further to £8 per ton, and in 1831 to even £2 per ton. In 1845 the manufacture of iodine commenced and kelp was again in demand. The imports and prices are shown in the following table (p. 69).

It was impossible to give the imports of kelp earlier than 1845, as this table was obtained with difficulty from indirect sources, the Clyde trust having disposed of their books previous to 1859, thus rendering the early history of this interesting subject at present inaccessible for statistics.

It is shown that a large number of makers of iodine in Glasgow at that time had been now reduced to three.

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* *Vide* Compt. Rend. lxxxiii. pp. 323–325.

† Published *in extenso* in the 'Chemical News,' 1877.

Kelp imports into Clyde, years ending June 30

Tons of Kelp	8858	8174	8116	8178	9207	9384	10040	9443	10823	8645
Price of Iodine per lb	10/	12/	12 8	13/	12 8	14/4	34/	24 8	15 8	10 8
								Average	Kelp	9187
								Pr of	Iodine	15/11½
Year	1856	18 7	1858	1859	1860	1861	1862	1863	1864	1865
Tons of Kelp	6349	8641	8123	8190	7754	9722	9414	14018	11349	13741
Price of Iodine per lb	13 8	12/4	10/6	9/8	8/6	7/	5 8	5/	8 4	7/8
								Average	Kelp	9730
								Pr of	Iodine	8/10
Year	1846	1847	1848	1849	1850	1851	1852	1853.	1854	1855
Tons of Kelp	3 27	4000	4400	4731	11421	7320	5418	6491	4679	5826
Price of Iodine per lb	21 3	11/	11/	11/	10 8	8 8	15/	15/4	12/	13/4
								Average	Kelp	5811
								Pr of	Iodine	12/11
Year						1841	1842	1843	1844	1845
Tons of Kelp						2565	1887	1905	3263	6086
Price of Iodine per lb						5/	4 8	6/	12/	31/1
								Average	Kelp	3133
								Pr of	Iodine	11/9

The working of kelp for iodine is minutely described, with the remark that all the text books on the subject describe only processes and apparatus abandoned by manufacturers many years ago The large production of iodine which may be expected from the Chilian caliche is fully investigated and it is shown that the possible production far exceeds the utmost output of Great Britain and France, but there are difficulties in the manufacture which have hitherto prevented very large imports from this source

The quantities of iodine in several species of sea weed, and from a large number of analyses of specimens from all parts of the coast, are tabulated The author shows that all sea weeds contain iodine, but few contain it in the quantity worth working

These are the deep sea algæ exclusively

His own researches are alluded to (Society of Arts, Silver Medal, Feb 14, 1862) in reference to the great loss of iodine in the present wasteful method of burning kelp, and his suggested improvement of collecting the winter tangle, now generally wasted, and distilling it in closed retorts, is described The sea weed is thus converted into charcoal (which remains in the retorts), and ammoniacal liquor, and tar condensed in suitable condensers, and gas, which is used to light the works

The gas liquor yields ammonia and acetic acid From the charcoal, the salts of potassium and sodium, with iodides and bromides, are easily washed out, and a residual charcoal is obtained which resembles that from bones This charcoal is fully equal to animal charcoal as a decolorizer and deodorizer, and can be very cheaply obtained

The manufacture affords winter employment to a large and indigent population in the winter, when they most need it It has been carried out on a large scale in some of the outward Hebrides, and has quadrupled the produce of iodine and greatly benefited the people.

On Lead Desilverizing by the Zinc Process By J E Stoddart

On the Atomicity of Oxygen and on the Constitution of Basic Salts.

By J Johnstone Stoney, *F R S*

On Zinc. By D Swan.

On the Prevention of the Pollution of Rivers By Rev. R Thomson

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On the Growth of Mildew in Grey Cloth By William Thomson, *F R S E*

The author described the size used by Lancashire manufacturers, which is nearly always more or less strongly acid

Two series of experiments on the relative actions of salts, often added by manufacturers to their size, in aiding or retarding the development of mildew, showed that the free acid present together with dampness is the most fruitful cause of mildew, and if the acid be neutralized with soda ash, mildew develops with much difficulty, and only after a very considerable lapse of time

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On the Nitroso Derivatives of the Terpenes By W. A Tilden, *D.Sc*

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y Note on a new Iso-purpurine B

On the Prevention of Fraudulent Alterations in Cheques &c By I Wai

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On the Means of Suppressing Alkali Waste By Walter Weldon

New Cotarnine Derivatives By C R Alder Wright, *D Sc*

When dilute bromine water is added to a solution of cotarnine hydrobromide combination takes place and a crystalline orange precipitate is thrown down consisting principally of *dibrom hydrocotarnine hydrobromide*, if excess of bromine be used, the precipitate chiefly consists of *tribrom hydrocotarnine hydrobromide*, these two brominated bodies being formed thus —

$$\underset{\text{Cotarnine}}{C_{12}H_{13}NO_3, HBr} + Br_2 = \underset{\text{Dibrom hydrocotarnine}}{C_{12}H_{13}Br_2NO_3, HBr}$$

$$C_{12}H_{13}Br_2NO_3, HBr + Br_2 = HBr + \underset{\text{Tribrom hydrocotarnine}}{C_{12}H_{12}Br_3NO_3, HBr}$$

If hydrocotarnine hydrobromide be used instead of cotarnine hydrobromide, and excess of bromine be added, the same tribrom-hydrocotarnine hydrobromide is formed, thus —

$$\underset{\text{Hydrocotarnine}}{C_{12}H_{15}NO_3, HBr} + 3Br_2 = 3HBr + \underset{\text{Tribrom hydrocotarnine}}{C_{12}H_{12}Br_{12}NO_3, HBr}$$

Dibrom-hydrocotarnine hydrobromide loses the elements of hydrobromic acid, forming *bromocotarnine hydrobromide* on boiling with water, aqueous caustic potash, or alcoholic silver hydrate, thus —

$$C_{12}H_{13}Br_2NO_3, HBr = HBr + C_{12}H_{12}BrNO_3, HBr$$

The bromocotarnine thus formed resembles cotarnine in many respects, its salts are crystallizable and very soluble, the base when crystallized from ether is represented by $C_{12}H_{12}BrNO_3, H_2O$, the associated water being lost at 100° with partial decomposition just as with cotarnine When heated to about 180°, hydrobromic acid is evolved, the residue contains a blue product insoluble in boiling alcohol, benzene, chloroform, petroleum, turpentine, carbon disulphide, and ether, but sparingly soluble with a brilliant blue colour in boiling glacial acetic acid, glycerine, or aniline, and readily soluble in cold concentrated sulphuric acid to a most intensely coloured magenta liquid the colorific power of this body is most remarkable, a minute speck scarcely visible giving a deep coloration to a considerable bulk of acid. As yet this body has not been obtained in sufficient quantity and sufficiently pure for analysis; the fact that concentrated warm sulphuric acid does not char it, but only dissolves it, suggests some constitutional similarity to indigo.

Tribrom-hydrocotarnine hydrobromide breaks up, on heating to 180-200°, in accordance with the reaction,

$$C_{12}H_{12}Br_3NO, HBr = CH_3Br + HBr + C_{11}H_8BrNO_3, HBr,$$

methyl bromide and hydrobromic acid being evolved and the hydrobromide of a new base being left. After due purification the free base is obtained from 80 per cent. alcohol in bright *orange* crystals containing $C_{11}H_8BrNO_2, 2H_2O$, the water of crystallization being lost at 100° and a brilliant *crimson* anhydrous base being left. This crimson mass is a delicate test for the presence of moisture in nearly absolute alcohol; when crystallized from such containing only a minute trace of moisture *orange* hydrated crystals are thrown down on cooling, whilst *crimson* anhydrous crystals are formed when very carefully dehydrated alcohol is employed; it may be noted that long standing over and distillation from a large bulk of quicklime does not sufficiently dehydrate ordinary 90 per cent. spirit to give crimson crystals by this test.

The salts of this base readily crystallize; the hydrochloride and hydrobromide are of a straw-yellow colour and sparingly soluble in cold water; on adding sodium carbonate to the warm only slightly yellow aqueous solution bright orange crystals of the free base separate rapidly on stirring.

The bromine in this base is apparently incapable of elimination by nascent hydrogen; it is proposed to designate it *bromotarconine*, "tarconine" (anagram of narcotine and of cotarnine) being the (as yet hypothetical) non-brominated base $C_{11}H_9NO_3$, differing from cotarnine ($C_{12}H_{13}NO_3$) by the elements of marsh-gas.

On the Alkaloids of the Aconites. By C. R. ALDER WRIGHT, *D.Sc.*

The results communicated to the Association last year, together with those obtained by Duquesnel, seem to point to the inference that when a mineral acid is used to acidify the alcohol used in the extraction of alkaloids from aconite roots, alteration of the base or bases originally present takes place to a greater or less extent, owing to the influence of the heat employed to evaporate the alcoholic extract; whereas if tartaric acid be used, and the extract be evaporated at as low a temperature as possible, as in the experiments of Duquesnel, much less alteration takes place and a considerable amount of a base crystallizable from ether is obtained.

Two cwt. of *Aconitum napellus* were worked up by this latter process for the purpose of examining more closely the character of the crystals thus obtained; the extract, evaporated gently to a small bulk, was treated with water and filtered from precipitated resin; the aqueous filtrate then yielded a semicrystalline precipitate when treated with potassium carbonate in slight excess. This precipitate was fractionally crystallized from ether and other solvents, and finally split up into a large number of fractions; no evidence, however, could be obtained of the presence of more than one crystalline base; all the fractions, when sufficiently purified from a small quantity of an obstinately adherent non-crystalline base of lower molecular weight, gave identical numbers agreeing with the formula $C_{33}H_{43}NO_{12}$, the gold salt being indicated by $C_{33}H_{43}NO_{12}, HCl, AuCl_3$.

This crystallized base, to which it is proposed in future to restrict the term *aconitine*, is eminently active physiologically, and agrees closely in all its properties with the "crystallized aconitine" of Duquesnel obtained by the same process, the different formula arrived at by Duquesnel (viz. $C_{27}H_{40}NO_{12}$) being apparently due either to impurity in the substance examined or to analytical imperfections.

The base, crystallizable from ether, obtained in small quantities from *A. napellus* by extraction with alcoholic hydrochloric acid, as described in the Brit. Assoc. Rep. 1875, p. 38, gave last year numbers from which the $C_{33}H_{45}NO_{11}$, or one closely similar, was deduced; after further purification, however, this substance was found to be perfectly identical with the aconitine above described, giving numbers represented by $C_{33}H_{43}NO_{12}$.

In order to purify aconitine completely from another base which does not crystallize from ether, but which obstinately adheres to aconitine when crystallized from that and other menstrua, it is sufficient to dissolve the approximately pure snow-white crystals already crystallized several times from ether in warm dilute hydrobromic acid; on cooling and standing well-defined crystals of the hydrobromide of aconitine separate, the other base being completely retained in the mother liquors; the drained and washed crystals yield perfectly pure aconitine on dissolving in water, precipitating by sodium carbonate, and crystallizing the precipitate from ether. This non-crystalline base does not appear to form crystallizable salts; it has a considerably lower molecular weight than aconitine. Whether it is originally present in the roots, or is formed by alteration of the crystallizable aconitine during the extraction process, is not yet made out.

These results, and those obtained last year, clearly point to the desirability of substituting for medicinal purposes the uniform homogeneous crystallized base (or a salt thereof) for the more or less amorphous mixtures of aconitine and other substances and alteration products usually found in pharmacy, inasmuch as some at least of these admixtures are considerably less physiologically potent than aconitine, $C_{3}H_{4}NO_{12}$.

Further experiments on the constitution of aconitine and the amorphous base or bases are in progress.

GEOLOGY

Address by Professor J. YOUNG, *M.D., F.G.S., President of the Section.*

WHEN the British Association met in Glasgow twenty-one years ago Sir Roderick Murchison presided over Section C, and was surrounded by a brilliant company, whose names, now historical, were even then familiar for their accuracy of observation, for philosophic generalization, and for the eloquence with which their science was clothed in words that charmed while they instructed—Lyell, Hugh Miller, Sedgwick, Jukes, Smith of Jordan Hill, Thomas Graham, Agassiz, Salter, Leonard Horner, John Phillips, Robert Chambers, H. D. Rogers, Charles Maclaren, Sir W. Logan: the list is a heavy one even for twenty-one years; and the changed circumstances will be fully realized by Nicol, Harkness, Egerton, Darwin, Ramsay, and others when they find Murchison's place occupied by one who holds it rather by the courtesy of the Council to the Institution in which we are assembled than by any claim he has to the honour.

It would be out of place for me to do more than refer to the Geological advantages which have given to Glasgow its commercial greatness. In the Handbook prepared at the instance of the Local Committee will be found gathered together all the positive knowledge we possess regarding the mineralogy, stratigraphy, and palæontology of the west of Scotland. The specimens themselves are exhibited in the Hunterian Museum and in the Corporation Galleries; and I take it upon me to say the Glasgow geologists are as ready as ever to assist the investigations of students in special departments with all the material which richly fossiliferous strata yield and the careful skill of assiduous collectors can secure.

Thus relieved from entering into local details, I would ask your attention for a short while to some of the difficulties which a teacher experiences in summarizing the principles of Geology for his students.

I may be pardoned for reminding you that as yet there are in Scotland only two specially endowed teachers of Geology. In the Universities, that science for which Scotsmen had done so much received only the odd hours spared from Zoology. In 1867 the two courses were separated in Glasgow; in 1870 Sir R. I. Murchison founded the Chair of Geology in Edinburgh; in 1876 Mr. Honyman Gillespie endowed a Lectureship on Geology in Glasgow, not separating it from Zoology, but rather desiring the two to remain associated, while means were provided for tutorial instruction in the elementary work of the class. When next the Association meets in Glasgow, I hope that the services which science has rendered to mining and metallurgy may have been recognized by those who have reaped the benefit. During the efforts of years to obtain provision for systematic teaching in Mining and Metallurgy, practical and scientific have always been set in opposition by those whom I addressed. In another twenty years it may have become apparent that it is possible for a man to be both practical and scientific, and that the combination is most conducive to economy.

Geology occupies the anomalous position of being a science without a special terminology, a position largely the result of its history, but to some extent inherent in its subject-matter. Treated of by Hutton and Playfair and their opponents in the ordinary language of conversation, current phrases were adopted into science, not so much acquiring special meanings as adding new ambiguities to those already existing. Every one seemed to understand them at once; and thus, as no one was obliged to attach very precise meanings to them, the instruments of research became its impediments, and the phrases in common use at the beginning of the century have transmitted to the present day the erroneous ideas of those by whom they were first employed. When Lyell, in 1832, methodized the knowledge accumulated prior to that date, he had, in organizing the science, to choose between inventing an appropriate terminology and adopting that in common use. By doing the latter he promoted the popularity of the science, though at the cost of some subsequent confusion; by attempting the former he would have set in arms against him those who would, according to the pedantry of the time, have denounced his neologisms and found in them a decorous veil for the objections which they entertained on other grounds to his views. Lyell was not the man to face the latter difficulty; nor can it be charged against him that he was wittingly neglectful of the interests of science. But to the use of conversational language are traceable certain assumptions to which I desire to draw your attention. In venturing criticism of this kind I am not unmindful of the Nemesis which has overtaken my colleague, Sir W. Thomson for his comments on Lyell's language. Thomson took exception to language which implied a kind of perpetual motion, a circulation of energy at variance with the teaching of physics; and, behold, two or three years after, Lockyer has published, as a physical astronomer, and Prestwich has approved, as a geologist, the opinion that the temperature of the sun may have fluctuated, that, in fact, changes of chemical combination may from time to time have refreshed the heat of the planet, whose uniform rate of cooling Sir William had assumed.

When stratigraphical geology first received due attention, the notion was prevalent that each formation terminated suddenly by cataclysm; it was therefore natural that the British succession, the earliest to be tabulated in detail, should be taken as a standard for other countries, and that the enumeration of the series should be a generalized section in which were incorporated those strata not present in Britain. The "intercalation" of beds thus practised to make an "incomplete" series "complete," still survives, as do the terms, though the notions which underlie them are formally denied by those who use them. A patriotic fellow-countryman once surprised us by his vehement denunciation of a treacherous Scot who called the Lanarkshire Limestones meagre and incomplete as compared with the English. With knowledge he might have made his criticism useful; as it was, he only gave a fresh example of the national peculiarity which, if it cannot prove Scotland to be better off than its neighbours, is content if it can make it out to be no worse. The abundant fossils of the Mesozoic strata of England and France rendered comparison easy, and created the impression that conchology was the A B C of geology, physical being subordinated to palæontological evidence. The balance has been somewhat restored by the Geological Survey, the precision of whose physical observations enables them to guide the palæontologist as often as they have to be guided by him. But one legacy from our predecessors we have not got rid of; nor, indeed, has its value been much called in question.

The process of intercalation had at first to do only with observed gaps, into which obvious equivalents could be received. But as the needs of speculative Biology rapidly increased, in the same ratio did belief in the imperfection of the geological record increase, till now we have that record described as a most fragmentary volume, nay, as the remains of the last volume, whose predecessors are lost to us.

Sir W Thomson did good service by calling in question, on physical grounds, the indefinite extension backwards of geological time The firstfruits of his crusade were the definitions of Uniformitarianism and Evolution which Prof Huxley gave. Henceforth no one will maintain the onesided notions regarding these two opposing views of the earth's history which were adopted in ignorant misconception or dictated by conceit and bigotry But the service done was even greater, for while it became clear that a knowledge of physics was indispensable to him who would promulgate sound notions, it was further apparent that both biological and geological evolution had a limit in time, that in fact, on the assumption of the primitive incandescence of our globe, the date might be at least approximately fixed when the mechanical processes now at work commenced and when the surface of the earth became habitable Nothing more has yet been done than to point out the way, for, though Prof Guthrie Tait indicates a limit of from 15 to 10 millions of years, that statement can only be regarded as in effect, though not perhaps in intention, a protest against the liberality and vagueness of Sir W Thomson's allowance, which gave geologists a range of from one to two hundred millions of years

The reconciliation of physicists and geologists is not likely to come through Mr Lockyer's researches, even if the earth's history be shown to have been identical, unless the renewal of the earth's heat be shown to be compatible with continued life on the surface If the reconciliation is looked for through the prolonged duration of the sun's life, that being the gauge of the earth's duration, the expectation is still based on the supposed need of very great time for geological processes, or rather on the supposed need of very great time for biological evolution, to which geological evolution has been squared There is another direction in which these results may help us to meet the limitation assigned by the physicists the intervals of variation of temperature may be shorter than those which separate the maxima of eccentricity of the earth's orbit, and thus the repeated cold periods of which we have suggestions in the stratified rocks, may have recurred within a shorter total period than is at present claimed

It is scarcely within the compass of this address to enter into the questions involved, but it is permissible to indicate the reason for delaying meanwhile acceptance of any precise limit of time There is as yet too much diversity of opinion as to the elements of the problem Physicists are by no means at one as to the conditions which permit or prohibit shifting of the earth's axis Calculations are based on the assumption of the regularity of the earth's form, under a certain constant relation of the masses, albeit of diverse specific gravity, which compose it. It is moreover assumed that the ratio of land and water have been uniform, though the formation of the grand features of the land by contraction of the cooling mass has not yet been considered as affecting this assumption by altering the disposition of the water. On the one hand it has been shown that the existence of uniform temperatures over the earth's surface is a gratuitous hypothesis, on the other hand it is clear that the existing distribution of light and heat is incompatible with the flourishing of an abundant Carboniferous and Miocene flora within a short distance of the north pole One expects that astronomers will look to the shifting of the axis of rotation as the possible explanation of the difficulty, taking into account likewise the shifting of the centre of gravity necessarily following those displacements of matter which, on the contraction theory, have determined the positions of the main continents and oceans

Mr Evans, in his address to the Geological Society, referred to the deviation of the magnetic axis as perhaps due to such shifting of the materials composing the inner mass of our globe May not the conjectures of M Elie de Beaumont be after all in the right direction? May not the change of trend which led him to classify the mountain-chains by reference to the age at which they had been elevated, be associated with movements which did not in all cases result in shiftings of the earth's axis so pronounced as those which permitted the Carboniferous and Miocene floras to invade successfully the arctic regions, or the phenomena of the glacial epoch, or epochs, to manifest themselves in the low latitudes where their traces have been recognized?

Waiving, for the present, inquiry into the influence which the admission of a possible shifting of the earth's axis might have on our estimate of geological time, I shall return to the phraseology whose amendment seems advisable.

The confusion which exists is well illustrated in a remark by an eminent writer to the effect that the progress of geological research tends to prove the continuity of geological time. The phrase in itself involves an absurdity; but what is meant is, that the successive so called formations pass into each other by imperceptible *gradation*, and that as time goes on, we shall be more and more able to intercalate strata so as to present a continuous scale of animal and vegetable forms. This is one out of many samples of the extreme length to which the thirst for strict correlation may go. We find in Murchison's writings and elsewhere pointed protests against the succession of strata in one district being held to rule that in other districts; but these are rather concessions wrung from their author by the pressure of particular instances than acknowledgments of a rule applicable to contiguous and to distinct localities alike. I could not perhaps take a better example than the strata which contain the remains of the fossil *Lyndæ*. If we arrange the fossils in any series representing the modification of particular structures, or averaging the modifications of all the structures, we shall find that the terms of the series are met with, now in Europe, now in America, yet no one would venture to intercalate the European in the American Tertiary series so as to square the geological record with an assumed zoological standard. The notion of gradations, the extreme view of correlations, has led to results which are, to put it mildly, of doubtful value. Yet it was a natural result of the work of Cuvier and other palæontologists among the Mesozoic and Eocene fossiliferous deposits. The statistical method invented by Lyell is simply a *mode of gradations*. Intercalation of strata is therefore a survival from an earlier stage of the science, and carries with it a distinct echo of the catastrophic notion that strata were formed simultaneously and generally over the earth's surface, if not universally.

The geological record has been compared to a volume of which pages have here and there disappeared, and the incompleteness of the record has been inferred from the frequency of pronounced gaps in the succession of strata. Of these gaps, these unconformities, Prof. Ramsay has shown the importance by demonstrating that they represent the lapse of unknown, but varying, and in all cases considerable periods of time. The intercalation of strata assumed to fill up the gap, and hereby to give symmetry to systematic classifications, can only be done by an appeal to the statistical method, a fauna containing forms characteristic of higher and lower beds being assumed to represent an intermediate point in time, whereas it might be equally well claimed as representing an intermediate area in space, and as being possibly representative of the whole gap and of some of the strata above and below it.

The definition of a formation as representing a certain period of time, still repeated with various modifications, is to blame for this and several other curiosities of procedure. But the climax of symmetrical adjustments is reached when we find "natural groups" established—when, in other words, an attempt is made to show a regular periodicity of phenomena in Geology. Dawson proposed a quaternary, Hull a ternary classification—to neither of which should I now refer, but that the deserved estimation of these writers is apt to perpetuate what seems to be an unsafe view of geological succession.

Hull's arrangement has the merit, by force of its simplicity, of bringing the vainness of the attempt into prominence. Dawson has complicated his classification so as to render it impracticable. A natural group of strata, one in which elevation, deep depression, elevation, record themselves in rocks so as to establish geological cycles, implies several things for which we have no evidence. Most important of all, it implies that the events above noted should recur in every area in the same order, that they should recur at equal intervals of time, and therefore yield equal masses of strata, and, above all, that the superior and inferior limits of each natural and conterminous group should consist of a mass of similar strata, one portion of which shall belong to the earlier, the other to the later group. Here then we have implied, not catastrophic simplicity as regards the strata, but something very like it as regards the subterranean forces.

Mr. Hull has not, however, been able to surrender himself wholly to his speculation. He has admitted "Gaps"—breaks, that is to say, for which he finds no equivalents in the British series—the strata that should occupy these gaps having been either removed by denudation or never deposited, the British area being at these times above water The concession is fatal to the scheme But the very use of the word gap recalls the phrases "complete" and "incomplete," and their nearest of kin, "base of a formation" Prof Ramsay used the word "break" to mark his unconformities, but no term has been proposed for "the base of a formation" The term was in constant use when such base was always claimed to be a conglomerate. That notion is now exploded; but no distinction is drawn between the lowest bed of a group of conformable strata, and the bed or beds which repose unconformably on those below them Thus the London Basin has the Thanet beds, the Reading beds, and the London Clay successively resting on the Chalk, and each of these is the base for its proper locality, unless it be asserted that in this and similar cases the lowest beds once covered a wider area and were then removed But a more important case is presented by the great calcareous accumulations of the Carboniferous and Chalk series The Lower Greensand is to the latter series in England what the lowest stratum of the chalk would be if we could get at it The Carboniferous Limestone rests directly on the Red Sandstone in Central England, further north it rests on the Calciferous Sandstones Thus the base of the formation varies according to locality, or rather according to the circumstances of deposition, and we need a term which would indicate a difference between the conformable and unconformable succession Mr Judd has lamented the equivocal use, by English writers, of the term formation, which etymologically is as well applied to the Chalk without flints as to the whole Cretaceous series. He advocates "system" as applicable to the larger groups—the Cretaceous system for example But it seems as if the time were come for still further restrictions of either or both terms

The analogy of the geological record to an incomplete volume is, like most analogies, at once imperfect and misleading Rather might the record be compared to the fragments of two volumes which have come to be bound together, so that it is not possible to recognize the sequence Or perhaps it might be better compared to a universal history in which, by omission of dates, the chronology is thoroughly obscured, and the necessary treatment of each nation by itself conceals the contemporaneity of events We have the aquatic record and the terrestrial record, and these two are going on simultaneously It is as yet, and probably always will be impossible to recognize the marine deposits which correspond to the terrestrial remains, save perhaps in the most recent geological times We now know that the life of the Cretaceous seas is not wholly extinct in the existing Atlantic Ocean, but exists there to an extent which would entitle the deposits of that area to rank by the statistical method as intermediate between the Cretaceous and the Tertiary It is obviously impossible to include under one term deposits which are associated with geographical changes so important as those commonly accepted as having prevailed during the Tertiary epoch. The Mesozoic forms pass gradually into the Tertiary; how gradually we cannot say, since the deep-sea equivalents of the European Tertiaries are not certainly known to us But as a portion survives to the present day, and as, presumably, the extinction was not rapid (for it is only in the case of land-animals that sudden disappearances are as yet probable), it is obvious that the successor, the heir, of the Chalk was not the Eocene, nor necessarily the Miocene known to us, but probably deposits still buried under the Atlantic

My object is to show that even the limitation of time which Prof Tait prescribes for us may not after all be too narrow for the processes which have resulted in our known stratigraphy Mr Darwin speaks of the geologic record being the imperfect record of the last series of changes, the indefinite extension of time anterior to the earliest fossiliferous rocks being necessary for the full evolution of organic forms. But is there any ground for the assumption? True thát the Laurentians contain fragments of antecedent rock, but were these fossiliferous? Are they the remains of land surfaces on which living beings flourished? or are they only the débris of the first consolidated portion of the Earth's crust, on which if organisms existed they may have been the most primitive of our organic series? Mr. Jukes refers to the possibility of such earlier strata having existed; but he wrote when geologists were dominated by the belief in the indefiniteness of geological time. Now we are brought by physicists like Sir W. Thomson and Captain Dutton to face the question, Is there evidence of such earlier masses of stratified deposits? If we allow to the physical argument all the weight to which its advocates deem it entitled, if we accept 15 millions of years, nay, even if we admit 100 millions of years as our limit, it follows that we may still regard the earth as in its first stage of cooling But when we turn to the geological evidence, all that can be advanced is that the Laurentian strata contain fragments presumably derived from earlier strata, but metamorphosed fragments among metamorphic rocks are not the most reliable guides, and there is the positive evidence that the Laurentian area has not been covered to any extent, if at all, by later deposits So far as direct proof goes, therefore, we have none that the earliest known stratified rocks are not also the earliest deposited after cooling Even if we disregard the limits imposed by the philosophers, liberal though they are in Sir W Thomson's hands, the absence of proof that later deposits covered Laurentian areas seems entitled to greater weight than is usually allowed to negative evidence At best the assertion of antecedent strata is an arbitrary one, which any of us is at liberty to contradict, and in favour of which no physical evidence, and only zoological prejudices can be adduced The earliest stratified deposits known are the Laurentian, and they are, so far as we know, the earliest to have been deposited

But apart from these possible though improbable earlier deposits, geological time is said to be lengthened by the missing strata of later periods Mr. Croll has given great prominence to this, which is another of the things taken for granted in geology Commenting on Mr Huxley's remark that if deposit went on at the rate of 1 foot for 1000 years, the 100,000 feet of strata assumed by him to form the earth's crust would be laid down in the 100 millions of years which Sir W Thomson had given as the limit, "But," says Mr Croll, "what of the missing strata?" It is commonly said that we have only a part of the deposits of any period, that the last have been denuded away, and that thus the time needed for their deposit and for their subsequent removal are out of our knowledge This is based on what we see on the shore when the tide rises and falls and washes off at each turn a part of the sand and mud laid down in the interval But the older deposits were laid down in deeper water than that between tide-marks, and were for the most part laid down during subsidence Even admitting removal of part of the strata to have taken place during re-emergence, the quantity so withdrawn cannot be proved to represent more than a small fraction of the total. To provide the needed elongation of geological time by an appeal to arbitrary speculations is not admissible. Belief on belief is, as Butler says, bad heraldry The denudation to which importance is justly ascribed is that represented by an unconformity Re-elevation has been accompanied by disturbance of the area from a different centre than that around which subsidence took place. The strata are worn obliquely, and thus thickness of the mass at one place is greatly diminished, though it does not follow in all cases that the maximum thickness of the strata has been affected

The importance—as I deem it, the excessive importance which is attached to the missing strata is asserted by biologists, who apparently unconsciously seek to gain, by prolonging the interval between successive groups, the time which ought rather to be sought for in tracing, were that possible, the migrations of the species which seem to have suddenly died out In other words, there is a reversion to the older ideas regarding the succession of strata which are embodied in such phrases as the Age of Fishes, the Age of Reptiles, and the like.

But the inequality of surface which unconformity involves, entails that other consequence, that the maximum thicknesses of the two masses of deposits do not coincide in position Hence the thickness of the strata in the area will be exaggerated, the time spent in deposit also exaggerated, if the two thicknesses are put together. This has been done by Mr. Darwin in drawing inferences from the measurements given him by Prof. Ramsay, measurements which, on the face of them, do not represent a continuous pile of rock. Mr Darwin assumes either that the Welsh hills (not to speak of the Hebrides) were covered by all the later strata now denuded—or that if we sunk a bore, say on the east coast, we should go through the whole series as tabulated. When Prof Huxley took 100,000 feet as the thickness of the sedimentary series, the same notion was unconsciously present, the same survival of catastrophism—the onion-coat theory, as Herbert Spencer named it.

The Geological Survey has corrected its tables in one important direction: it has shown the contemporaneity of unlike groups in different parts of Britain, the distinct types of the Old Red Sandstone, Carboniferous, Permian and Purbecks being placed in parallel columns. To some extent this is a curtailment of the thickness of the rock series: the dissimilar strata are not piled on each other. But the curtailment might be carried still further. The marine and terrestrial conditions are simultaneous: if we could identify the dry land for each deep sea, we should have possibly the overlap of periods producing extraordinary combinations, though not perhaps Mesozoic and Palæozoic faunas contemporaneous. But the British series may be tabulated as follows:—

Land Surfaces	*Lacustrine & Fluviatile*	*Marine*
		Laurentian?
	Cambrian	Silurian
	Old Red Sandstone	
Coal Measures	Calciferous Sandstones	Carboniferous Limestone
Permian		
Trias		Jurassic
Purbeck		
Wealden		Neocomian
Miocene		
Pleistocene		Cretaceous

In the case of the Cretaceous series Mr. Ramsay has given illustration of the ingenious views of De la Beche regarding the contemporaneity of deposits superposed one on the other. The Lower Greensand is contemporaneous with part of the Chalk; so were parts of the Wealden; nay, even of the Purbecks a portion must have been forming while the Cretaceous sea was gradually deepening southward and eastward.

It may be said that the recognition of the parallelism would not make very much difference after all—that it would not one whit lessen the time spent in forming 500 feet of rock to know that there was elsewhere another 500 feet formed at the same time. But the shortening of the geological list by striking out the overlaps of the formations and thus counting them only once is of itself a matter of some consequence, since the maximum thickness of the Cretaceous being nearly 3000 feet and that of the Weald 1500 feet, even the partial coincidence in time of these masses would, on Mr. Croll's calculation of 1 foot of deposit per thousand years, make a considerable difference in the chronology; still more if the Carboniferous Limestone be set against its probable contemporaries the Upper Old Red Sandstone and Coal-Measures. Mr. Jukes's bold erasure of the Devonians was of itself a very important change in the chronological table, and I doubt not others may yet be achieved. But, it may be said, the Cretaceous still rests on the Wealden; the vertical thickness still remains. But is the ordinary method of estimating the thickness quite reliable? In some cases, as in the productive Coal-Measures, there is tolerable uniformity; but among the lower Coals and the Mesozoic strata, where the strata or groups of strata are not regular, the maximum thicknesses of all are, as has been already shown, apt to be taken; and thus an aggregate more or less in excess of the real thickness results.

But, recurring to an objection already referred to, arrange it as you like, you get, say in Wales, a known thickness of 50,000 feet. But the rocks there are tilted, and the absolute depth which they attain in this position is unknown. In North America the Laurentians are estimated at 30,000 feet; but though there is every reason to believe that they have not been covered to any extent with later deposits, the total thickness of the sedimentary crust is, for the same reason as in Wales, unknown. Bigsby has shown how varied are the surfaces on which the later deposits are laid down; how great therefore must be the deductions from the sum total of maximum or even average thickness of all formations before we approximate to the actual thickness of sedimentary deposits at any one point. But take the actual thickness in Wales as given in Jukes's Manual from the Survey data: for the Cambrians we have from 23000–28000 feet; Silurians, Upper and Lower, not counting breaks by unconformities, 20000. If denudation takes place at the rate of 1 foot in 6000 years, and deposit at the same rate, we should have for the Silurians alone 120 millions of years needed. If, however, deposit takes place at the rate of 1 foot in 14,400 years, 288 millions of years would be needed for the accumulation of the surviving strata. It is obvious that the rate of deposit or denudation or both are misunderstood. The stratified rocks equal in amount the material denuded; if we knew the total amount of denudation we should know, not merely the residuum of rock open to our inspection, but the total amount of stratified deposits which had been formed—or at least approximately, for the deposit of materials removed is not synchronous with their removal. Obviously these elements are not known, and cannot be known, to us. Mr Croll, who has investigated the question theoretically, assumes that deposit and denudation take place in equal times, and assumes further a uniform distribution over the whole or over a part of the sea bottom. But Prof. Geikie's table shows that, if we are to take averages as a safe guide, the land is lowered at the rate of 2 feet in 6000 years. Moreover, if, as Mr Croll points out, deposit was less during the Glacial epoch, the process must have been more rapid since; and thus an irregularity is introduced which impairs the value of the calculations. Prof. Hughes, in the brief abstract of his Royal Institution address, which alone I have had the opportunity of seeing, contests the validity of any estimates of time on the basis of our existing knowledge. I do not mean to enter into this question; but I may be allowed to remark that any conclusions founded on mean thickness of sedimentary formations are of no value. It is not the time necessary for the building up of a mean thickness, but that necessary for the formation of the maximum thickness in particular regions, which we have to consider.

If the Laurentian rocks and their equivalents are to be regarded as the earliest stratified deposits, or rather, if there is no reason for believing that they were preceded by other stratified rocks, the relation of Huxley's homotaxis to any classification of strata having the Laurentians as a fixed point is worth investigating. The universal diffusion of species in the earlier strata was first the accepted creed of geologists. Then it was denied, though the language of the earlier faith continued current. Again we return towards the doctrine of extensive simultaneous diffusion, but under a very much modified form. The 'Challenger' reports bear testimony to the wide distribution of forms in the deepest oceans; and when we turn from these and compare the lists of fossil species so found widely distributed, it appears that here again we have oceanic forms, or at any rate those found in such limestones as are safely assigned to a deep water origin. Ramsay has shown that the continental epochs in Western Europe overlasted considerable periods of time. The antiquity of the Atlantic and Pacific is certain; even their primitive character is possible. Thus there are two conditions, land and deep sea, reasoning regarding which must be quite different from that applicable to the intermediate conditions. It is exactly these intermediate states which present practical and speculative difficulty. Theories which account for mountains and oceans fail to explain the "oscillations" which were wont to be appealed to when terrestrial and marine surfaces succeeded each other. But the assumed movement of the land is by no means a certainty; and, as in the kindred case of faults, we need terms which shall be neutral, whether the land has moved upwards or the sea shrunk downwards. The terms Palæozoic, Mesozoic, and Cainozoic have long held their places from the reluctance to disturb established nomenclature, as well as from the difficulty of inventing appropriate substitutes; but if retained at all, we know now that the relations they represent are not the same for the terrestrial, the deep oceanic, and the intermediate areas, any more than the life is the same under those three conditions.

I have once before called attention to a grave difficulty in the physical geography of Scotland; and as Mr Seeley has since then raised the same question without obtaining an answer, I would again state the case, as one which seems to involve the revisal of some definitions.

The Silurian hills of South Scotland are commonly said to have been covered by Old Red Sandstone and even by Carboniferous strata—patches of these rocks being met with on the south side of the fault which defines these hills, with their abrupt, coast-like margin seen from Edinburgh or from Symington station on the Caledonian line. But the surface of these Silurians was denuded before the Old Red times, as Mr. Geikie has showed. Nay, valleys existed as now, and in the same positions as now. At the present time the rivers flow in identically the same valleys, in at least the cases of the Nith, the Annan, the Lauder, and the Liddell, and the boundaries of the areas are so well known that we can safely assert no buried channel to exist such as we find on the tributaries of the Clyde. That the channels were occluded in glacial times we may take for certain; that the obstruction has been washed away and the courses cleared is equally certain. The surface-contours were not materially altered, so that the retreating ice left hollows in the position of the old valleys. But the case is quite different when we deal with the older rocks. Their succession is marked by unconformities and overlaps, which it is impossible to picture as associated with full preservation of the surface-features on which they were laid down; and when the thickness comes to be as much as 1000 feet or more, and of that thickness a part at least made up of marine strata, the relapse of all the streams to their old courses is an event of the highest improbability. Mr. Topley has pointed out how the dip of strata may under certain circumstances coincide with their thinning out to the margins of their area of deposit, changes of angle in highly inclined strata pointing in the same direction. The ordinary rule of protracting strata and thus restoring their thickness over the adjacent high ground, is (in the case at least of South Scotland) a method which imposes on atmospheric denudation, even if aided by the sea, a most complicated task.

Had time permitted it might have been interesting to note the changing phraseology regarding faults, and the pertinacity with which phrases involving the most unsatisfactory and improbable causation continues to be used. Upcast and downcast, upthrow and downthrow, displacement upwards or downwards: these it may be said are of small importance; they are only symbols. But, in the first place, they are mischievous so far as they give students confused ideas with which to contend; and in the second place, the continued acceptance of loose phraseology is peculiar to geology. Even in metaphysics, where the subject-matter is much more conveniently discussed in ordinary language, new terms are employed to a great extent. But important as I therefore regard these terms from the teacher's point of view, the greater importance attaches to the accuracy of the notions which underlie our language regarding the processes and rates of deposit and denudation.

So far as our present knowledge goes, we must accept it as certain that there is some limit to the duration of the earth in the past. Neither philosophers nor astronomers are agreed on the essential points of the problem; nor have they considered all the possible changes in the position of the earth's axis and in the rate at which the earth loses heat. The limits hitherto prescribed are so discrepant that we cannot as yet accept any as fixed. Neither have geologists so accurate a knowledge of geological processes that they can speak with confidence either of the absolute or relative rates at which rock-formation has advanced. The geologist has hitherto asked for more time, not because he himself was aware of his need, but from a generous regard for the difficulties in which his zoological brother found himself when he attempted to explain the diversity of the animal series as the result of slowly operating causes. The geologist asked for more time simply because he could form no just estimate of what was needed for the physical processes with whose results he was familiar. But palæontological domination is now at an end; and the increasing number of geologists who are also competent physicists and mathematicians seems to mark a new school, which will strive to interpret more precisely the accumulated facts. Such at least seems the history of the past fifteen or twenty years. Such seems the direction in which speculation now tends; and in the foregoing remarks I have endeavoured faithfully to represent the drift of our science. To many here present much of what I have said is already familiar; I therefore give place to the more legitimate business of the Section, looking to receive elsewhere "such censures as may be my lot."

On the Physical Structure of the Highlands in connexion with their Geological History. By His Grace The Duke of Argyll, *K.T., F.R.S., F.G.S.**

The questions dealt with by Geological Science have now become so vast and various, that no one district of country can be expected to furnish illustrations of more than a very few of them.

The West of Scotland, in the capital of which we are now assembled, is not rich in deposits which illustrate the passage of animal life from the types that have become extinct to those which are of more modern origin and which still survive. No bone-caverns of importance have been discovered, and, with one exception, even our river-gravels and estuarine deposits have not been especially productive. That exception is, indeed, a great one. It was in this valley of the Clyde that the late Mr. Smith, of Jordan Hill, first discovered those indications of an Arctic climate recently prevailing which have ever since constituted a large and important branch of geological inquiry, and the full interpretation of which still presents some of the most curious and difficult problems with which we have to deal. But our Palæozoic areas, except the Coal Measures, are to a large extent singularly unfossiliferous. Neither the Scottish Oolite nor Lias has yielded any remarkable additions to the curious fauna of which in England and elsewhere they have yielded abundant specimens.

But, on the other hand, perhaps no area of country of equal extent in any quarter of the world presents more remarkable phenomena than the West of Scotland, in connexion with those causes of geological change which have determined the form of the earth's surface, and have given to its physical geography those features of variety and beauty which are the increasing delight of civilized and instructed men. We cannot descend the course of this river Clyde to the noble estuary in which it ends without having presented to us mountain outlines and an intricate distribution of sea and land which raise questions of the highest interest and of the greatest difficulty. From the northern shores of that estuary to Cape Wrath, in Sutherland, the country is occupied mainly by rocks of Silurian age, but so highly crystalline as to be almost wholly destitute of fossils, and so upheaved, twisted, contorted, and folded into a thousand different positions, that, except in one great section, it is most difficult to trace any persistent succession of beds. It is one great series of billowy undulations traversed by glens and valleys, some of which are high above the level of the sea, but many of which are now so deeply submerged that through them the ocean is admitted far into the bosom of the hills. These glens and valleys lie in many different directions, but there are so many with one prevalent direction as to give a general character to the map, a direction from N.E. to S.W., or parallel to the prevalent strike of the Silurian rocks. The shapes of the hills and mountains are not by any means wholly without relation to geological structure—because in a thousand cases the sloping outlines will be found to be determined by the inclination of the beds, and the precipitous or steeper outlines to be determined by the upturned or broken edges. In like manner there are cases where a crumpled or knotted outline is the index of beds deeply folded and contorted along anticlinal axes. But nevertheless there are also innumerable cases where no such relation can be traced, where the mountains seem to have been cut out of some solid mass, all the rest of which has been removed by some agency which left these great fragments standing by themselves, and of which the contours cut across the lines of structure at every variety of angle. Along the whole western face of this country it is guarded from the open ocean by an archipelago of islands, some of which are separated from the mainland by submerged valleys no broader than those which separate one hill from another in the inland glens. Many of these islands are wholly occupied by the debris and the outbursts of extinct volcanoes. The mountains which are thus composed bear, in many cases, the characteristic forms of lava-streams, but many others are not readily distinguishable in outline from the mountains of wholly different material which are near them. They reach the same general average level of height, here and there rising into peaks very similar to others of a widely different age and of a widely different material. Moreover all the islands partake largely of the general character of the mainland in having their deeper valleys submerged, and in being thus deeply indented by arms of the sea similar to those which give their peculiar outline to the adjacent coasts.

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It may serve to bring more vividly before you the facts of the physical geography of this country (for which it is one of the duties of geologists to account if they can) if I give you some statistical facts affecting the single county of Argyll, which begins on the northern shore of the Firth of Clyde. Following the coast-line of that county from the head of Loch Long, which is its southern and eastern boundary, to Loch Aylort, which is its northern and western boundary, and including its islands, we find it measures no less than 2280 miles in length, of which about 840 represent the sinuosities of the mainland and 1440 represent the coast-line of its larger islands. There are, besides, valleys which are now inland, and are occupied by freshwater lakes which evidently, at a recent period, were arms of the sea, and these represent a further line of coast, measuring 270 miles. There are 11 principal arms of the sea, each of them measuring from one to six and thirty miles in length. Two of these arms of the sea exceed the 100-fathom line in depth—Loch Fyne and the Linnhe Loch, and it is very remarkable that these deep soundings do not occur near the points where these lochs join the more open sea, but on the contrary far up their course or bed among the mountains. The ridges dividing these and other valleys vary in elevation from hills of very moderate height to the range of Cruachan, which immediately beyond the boundary of the county culminates in Ben Nevis, which rears its head almost on a level with Ben MacDhui, now ascertained to be the highest summit in the British Isles. But no statistics can give an idea of the intricacy with which sea and land are interfolded on our western coasts comparable with that which is gained by some of the many beautiful views which abound on the heights in the vicinity of Oban, whence the visitor can command the entrance of Loch Etive, with the course for many miles of the Linnhe Loch, of the Sound of Mull, the Sound of Kerrera, and the Firth of Lorne.

Now the question naturally arises—to what geological ages and to what geological causes do we owe, in its main features, this curious distribution of land and sea? I say in its main features, because, of course, the more superficial sculpturing of every mountainous country is undergoing incessant modification, and this modification may have been, and probably has been, very considerable indeed within times which, geologically speaking, belong to the existing age. But the question I put has reference to the epoch of past time, when the main outlines of hill and valley were determined, when the great mass of the country (which has been, I believe correctly, identified as composed of metamorphosed Silurian beds) was elevated into the various mountain chains which now constitute its characteristic features.

If the question had been asked some five and twenty years ago, I should have said that the evidence pointed to an age of great geological antiquity for the central group of Highland mountains, in some shape very like that in which we see them. All round the edges of the country there are the remains of the Old Red Sandstone, which often fit into the contour of the valleys and have left fragments in nooks and recesses of the hills. It would almost seem as if they had been the shores of the seas or great lakes in which that great system of deposits was laid down, and that they lifted their heads above those waters in forms not wholly unlike those in which we now see them. The total absence over almost the whole country of any other or later rocks, the absence among the débris of any material other than that of which the hills are themselves composed, would seem to confirm the same general conclusion.

Some doubt, however, may seem to have been thrown on this conclusion, since it has become certain that it cannot be true of at least one district of our western mountains, which is nevertheless closely related to all the rest, having the same general elevation, partaking of the same general bend of coast-lines, cut up by similar valleys, and fitting into the same contours of denudation. The district to which I refer is that of the volcanic islands which stretch from the south end of Mull to the north end of Skye. Since the discovery, which I was fortunate enough to make in 1851, of the leaf-beds of Ardtun, it has become clearly ascertained that these islands are the remains of volcanoes of that geological age to which an ever-increasing interest seems to attach—that middle age of the great Tertiary division of geological time to which Lyell gave the name of Miocene. The mountains of Mull, and of Eigg, and of Rona, and of Skye, with all their valleys and intricate lines of coast, have unquestionably an origin later than the Miocene—how much later, is the question of physical geography which geologists are called upon to solve.

It is possible, indeed, to suppose that the hills of the mainland might be of a very different age from those of the adjacent islands, and against this, until some two years ago, there would have been nothing to advance except the suspicious similarity and adjustment between the two groups the coincidence of their outlines, and of the way in which they have been cut and carried. But the admirable researches of Mr Judd, in 1874, have brought one little fact to light which speaks volumes for the enormous changes which must have taken place since the volcanoes of the Miocene over a portion at least of the Highland area, and which may, therefore, have taken place over the whole of it. The land upon which the Miocene vegetation flourished, and upon which the lava-streams of its volcanoes were poured out seems to have been for the most part a land consisting of Cretaceous and Secondary rocks. The fragments of that country which remain are generally consistent with the supposition that they were deposited in a sea which washed round the bases of the Highland mountains, but which never covered them. Like the fragments of the Old Red Sandstone, the remains of the Secondary rocks lie along the margins and fringes of the Silurian hills. But Mr Judd has made the startling discovery of an outlier of the whole series of the Secondary rocks, including representative beds of the Trias, Lias, Greensand, and Chalk, together with deposits, probably Lacustrine, all lying on the top of one of the mountains of metamorphic gneiss which constitute the district of Morven. This fragment has been preserved by having been covered by a sheet of lava from some great neighbouring volcanic centre, the position of which is probably indicated by Ben More in Mull. But the mass of volcanic trap which has covered up and preserved this relic of the Cretaceous land is itself a fragment occupying the top of a mountain of gneiss, separated from the remainder of the sheet of lava to which it belongs by deep valleys, precisely similar to those which divide the hills from each other throughout the whole area of the Highlands. This position of an outlier of the Cretaceous rocks on the summit of a mountain of gneiss is rendered still more curious by the circumstance that in that position the beds are not tilted or in any way apparently disturbed. They are arranged horizontally, as if the ocean floor in which they were deposited had occupied that level, or as if its deposits had been lifted up over so large an area that any small section of that area could retain its original horizontality. The Lower Silurian gneiss beds on which these Secondary deposits have been laid are violently twisted and contorted, and this structure must have belonged to them when they constituted the floor of the Cretaceous sea. The position of the Miocene basalts capping the Secondary deposits proves that the whole mountain, as a mountain, is of later date than the Miocene age—how much later we cannot tell, and thus that the causes of geological change which have cut up the country into its present form, though they doubtless began in very remote epochs, have at least been prolonged into a comparatively late age in the history of the globe.

It would, I think, be affectation to pretend that our science enables us to follow, with any thing like distinctness of conception, the exact nature and sequence of operations which through such a vast lapse of time have brought about the final result. But I believe in something like the following general outline of events.

First. That subsequent not only to the consolidation, but probably also to the metamorphism of the Lower Silurian deposits, the whole area of the Western-Central Highlands became an area of that kind of disturbance which arose from lateral pressure due to secular cooling and consequent contraction and subsidence of the crust of the earth.

Second. That the crumpling, contortion, and tilting of the Silurian beds which we now see arose from that disturbance.

Third. That then were determined those great general lines of strike running from N.E. to S.W. which are to this day a prominent feature in the physical geography of the country.

Fourth That during that period of disturbance, and as part of the movements which then took place, the disturbed rocks fell inwards upon materials at a great heat, which rose in a pasty state along the lines of least resistance, and thus came to occupy various positions, sometimes intercalated among the sedimentary beds

Fifth That to this period, and to this method of protrusion we owe some at least of the masses of granitic material which are abundant in the Highlands. In particular, that to this period belong the porphyritic granites on the northern shores of Loch Fyne

Sixth That during the later ages of the Palæozoic period, volcanic action broke out at various points, accompanied by great displacement and dislocation of strata, and that to this, with the denudation which followed, we owe much of the very peculiar scenery of the south-western coasts, especially in the district of Lorne in Argyllshire

Seventh That we have no proof that the Central Highlands were ever under the seas which laid down the deposits of the later Palæozoic age

Eighth That such evidence as we have points rather to the conclusion that they were not under those seas, since such fragments as remain of the Old Red and of the Carboniferous rocks appear to have been deposited round the bases and in the marginal hollows of the Silurian hills

Ninth That in like manner we have no evidence that the great mass of the Western or Central Highlands was ever under the seas of the Secondary ages, which on the contrary, appear to have deposited their sediment upon an area outside of, but probably surrounding, the area of those Central Highlands, and certainly upon their north-eastern and western flanks

Tenth That the whole area of the Inner Hebrides and of the waters dividing them, together with some portion of the mainland, as in Morven, was an area occupied by Secondary rocks.

Eleventh That in the Tertiary ages, probably in the Eocene, and certainly in the Miocene, these rocks formed the basis of a great land of unknown extent, very probably extending for a great distance both to the east and west of the present coasts of Scotland, and embracing the north of Ireland.

Twelfth That this country became in the Miocene age, and possibly earlier, the scene of great volcanic outbursts, which covered it with vast sheets of lava and broke up its sedimentary rocks with every form of intrusive plutonic matter

Thirteenth That later in the Tertiary periods, and perhaps as late as the Pliocene, this volcanic country was itself broken up by immense subsidences and upheavals, giving both occasion and direction to the agencies of denudation and to enormous removals of material

Fourteenth That this Tertiary country had been thus broken up and nothing but its fragments left when the Glacial epoch began, and that the main outlines of the country, as we now see it, had been already determined when glacial conditions were established

Fifteenth That thus the work of the Glacial period has been simply to degrade and denude preexisting hills and to deepen preexisting valleys

Sixteenth That during the Glacial epoch there was a subsidence of land to the depth of at least 2000 feet below the level of the present sea, and again a reelevation of the land to its present level.

Seventeenth That this reelevation has not restored the land to the level it stood at before the subsidence began, but has stopped greatly short of it, and that the deep arms of the sea or lochs which intersect the country, and some of the deeper freshwater lakes, such as Loch Lomond, are the valleys still submerged which at the beginning of the Glacial epoch where high above the sea and furrowed the flanks of loftier mountains

Eighteenth. That during the Glacial period the working of denudation and degradation was done, and done only by ice, in the three well-known forms —1st, of true glaciers descending mountain-slopes; 2nd, of icebergs detached from the termination of these glaciers where they reached the sea, and 3rd, by floe or surface ice, driven by currents which were determined in direction by the changing contours of the land during the processes of submersion and reelevation

It would be impossible on this occasion to illustrate or support these various propositions by going into the evidences on which they rest But as those of them which relate to the operations of the Glacial epoch express a decided opinion upon questions now involving much dispute, I must say a few words in explanation and defence of that opinion

It will be seen that I disbelieve altogether in the theory of what is called an Ice-cap, or, in other words, I hold that there is no evidence that there ever existed any universal mantle of ice higher or deeper than all the existing mountains, covering them and moving over them from distant northern regions

In the first place, this theory presupposes conditions of climate which must have prevailed universally over the whole northern hemisphere, whereas over a great portion of that hemisphere west of a certain meridian on the American continent, all traces of general glaciation and of any general distribution of erratics disappear

In the second place, the theory assumes that masses of ice lying upon the surface of the earth, more than mountain-deep, would have a proper motion of their own, capable of overcoming the friction not only of rough level surfaces, but even of the steepest gradients, for which motion no adequate cause has been assigned, and which has never been proved to be the natural consequence of any known force, or to be consistent with the physical properties of the material on which it is supposed to have acted

In the third place, as a matter of fact there do not now exist anywhere on the globe masses of ice which can be proved to have any motion of this kind, or to be subject to forces capable of driving and propelling it in this manner and with the effects which the theory assumes The case of Greenland, which is often referred to as an example, does not present phenomena at all similar to those attributed to the ice-sheet

In the fourth place, all the phenomena of glaciation which are exhibited on the mountain-ranges, including the distribution of erratics, can be adequately accounted for by the three conditions or forms of moving ice which have been above enumerated, and all of which are now in actual operation on the globe, namely — ice moving, not up, but down mountain-slopes by the force of gravitation, and ice floated by water and driven by currents as icebergs or as floes

In the fifth place, these phenomena of glaciation are essentially different from those which would result from the motion of a universal ice-sheet, even supposing it to have existed and supposing it to have had the (improbable) motion which has been ascribed to it

In the sixth place, and in particular, the mode in which erratics are distributed and the peculiar position of perched blocks are demonstrative of the action not of solid but of floating ice; whilst the surfaces of rock, which have escaped glaciation on one side and retain the deepest marks of it upon another, are equally demonstrative of exposure to moving ice under conditions which did not enable it to fit into the irregularities of surfaces over which it passed

In the seventh place, the phenomena seem to me to prove that some of the very heaviest work done by ice has been done towards the close of the Glacial epoch—when the land was emerging again from out of a glacial sea, and when all the currents of that sea, loaded with bergs and floes, were determined entirely by the outlines of the rising land

In regard to the much disputed question of the glacial origin of Lake-basins, the conclusion to which I have come is one which, to some extent, reconciles antagonistic views. I do not, indeed, believe that glaciers can ever dig holes deep under the average slope of the surface down which they move, but, on the other hand, they are the most powerful of all abrading agents in deepening their own bed and cutting away the rocky surfaces which lie beneath them.

If valleys thus deepened by the long work of glaciers and glacier-streams are afterwards submerged along with the whole country in which they lay, and if that submergence is accompanied by partial and unequal rates of subsidence, they would inevitably become hollows into which the sea would enter, or in which fresh waters would accumulate. In this sense, and in this way, it can hardly admit of a doubt that those lakes, which are nothing but submerged valleys, are due in part to glacier action, although the other half of the causation on which they depend is to be sought in the subterranean action of subsidence.

In conclusion, I would observe that although the fact of a great subsidence and a reelevation of the land during the Glacial epoch has been generally admitted to be one of the facts of which there is the clearest evidence, it is nevertheless a fact of which all the conditions and all the consequences have been most imperfectly recognized.

Without venturing to go so far back as to imagine the process of subsidence and submergence, let us only think for a moment of that movement of reelevation which has certainly been one of the very latest of the great movements of geological change. If it took place very gradually or very slowly, it necessitates the supposition that every inch of our mountain-surfaces, up to at least 2000 feet, has been in succession exposed to the conditions of a sea-beach. Yet where are the marks upon them of such conditions? We may suppose such marks to have been generally obliterated by later subaerial denudation. But against this is to be set the fact that the position and distribution of perched blocks and other erratics deposited by floating ice demonstrate, in my opinion, that very little indeed of such denudation has taken place since they were placed where we now see them. I could take any of you who are interested in this question to a precipitous hill near Inverary, some 1200 feet above the level of the sea, from the top of which you can look down on the masses of transported rock stranded upon its sides and base, precisely as one might look down from the top of some dangerous reef in the present ocean upon the debris of a whole navy of ships shattered upon it in some hurricane of yesterday. There they lie—some more or less scattered, some heaped upon and jammed against each other with sharp angles and outlines wholly unworn, and moreover so distributed that you see at a glance their strict relation to the existing heights and hollows of the land which must here have been the shoals and channels of the sea. These contours cannot have been materially changed since that sea was there. It seems that it must have been there, geologically speaking, only a very few days ago.

And this conclusion would seem to be confirmed when we observe the phenomena which are present in certain cases where the land has clearly rested for a considerable time and the ocean has left in raised beaches the evidence of its work at certain levels. Such raised beaches are to be found at many points all round our western coasts, but incomparably the finest and most instructive example of them is to be seen on the west coast of the island of Jura, near the mouth of Loch Tarbert, Jura, and extending for several miles to the north. These beaches are visible from a great distance, because their rolled pebbles are composed entirely of the hard white quartzite of the Jura mountains, which resists disintegration and is very unfavourable to the successful establishment of vegetation. I visited these beaches a few weeks ago, and, measuring the elevation roughly with a graduated aneroid, I found that they represent three more or less distinct stages of subsidence, one beach being about the level of 50 feet above the present sea, another about 75 feet, and a third at about 125 feet. Some others, which I saw only from a distance, appeared to be higher, and I believe, but am not quite sure, that further to the north they have been traced to the level of 100 feet.

But the feature connected with these sea-beaches, and especially with the lowest or the 50-feet beach, is the evidence it affords, first, of the length of time during which the ocean stood at that level, and secondly, and particularly, of the very recent date at which it must have stood there. As regards the length of time during which the ocean must have stood there, it is sufficient to observe the beautiful smoothness and roundness of the pebbles; they have been more thoroughly rolled and polished than the corresponding pebbles on the existing shores, equalling in this respect the famous pebble-beds of the Chesil Beach at Portland. Then, as regards the very recent date at which the ocean must have stood there, it is difficult to give in words an adequate idea of the impression which must be left on the mind of every one who looks at them. You see the curves left by the sweep of the surf, the summit level of its force, and the hollow behind that summit which is due to the exhausted crest—all as perfect as if it had been the work of yesterday. Is is difficult to conceive how ordinary atmospheric agencies, and even the tread of sheep and cattle, should not have broken such an arrangement of loose material. But there are exceptionably favourable circumstances for the preservation of those beds from absence of considerable streams and the protection of surrounding rocks. There is little or no evidence of glaciation anywhere around, and although it is certain that the sea which stood at those beaches so recently was a sea subject to glacial conditions, it is equally certain either that it continued to work there after those conditions had passed away, or, what is more probable, that that particular line of coast was protected from the drift of surrounding ice-floes.

If, now, we compare the evidence of recent action in these sea-beaches with the similar evidence connected with the position of erratics at far higher levels, which can only have been placed there by floating ice, I cannot help coming to the conclusion that the submergence and reelevation of the land to the extent of more than 2000 feet above the level of the present ocean has been one of the very latest changes in the history of this portion of the globe, and, moreover, that the reelevation has been comparatively rapid, probably by lifts or hitches of considerable extent, and that there were few, if any, pauses or rests comparable in duration with those recorded in the Jura beaches and in the cutting of the existing coasts.

Finally, let me repeat that whether this conclusion is correct or not (and I am well aware of the many difficulties which surround it), the general fact of submergence and reelevation is, perhaps, as certain as any conclusion of geological science, and that the consequences of it in accounting for the distribution of gravels and the most recent changes of denudation have never as yet been worked out with any thing approaching to consistency or completeness.

On the Sub-Wealden Exploration. *By* Major BEAUMONT, *M.P.*

On the Granite of Strath-Errick, Lough Ness. *By* JAMES BRYCE, *LL.D.*

The author described a granite tract a little distance from the shores of Loch Ness, and near the Fall of Foyers. This fall took place originally over a cliff of Old Red Sandstone, and this stone being of a soft character gradually wore away until it formed a magnificent basin almost inaccessible at the bottom, and the action of the water had also worn the rock back to the slate which came between it and the granite. His attention had been called to the Loch-Ness granite tract by hearing that gold had been found in the lower valley of the Nairn, which passes through this granite district, and he supposed it probable that the gold might have its source in this granite tract in the same way as he had found the granite of Sutherland to be the true source of gold. After describing the limits of the granite tract, he pointed out a most remarkable circumstance connected with its history, which was illustrated by a section in a glen above Innerfaricaig. Here this triple granite rises from the valley in a direction sloping eastward, at first leaning against the Old Red Sandstone, and ultimately, further east, regularly overlying it, the metamorphism being very remarkable through about a foot of depth, and portions of granite being embedded in the Old Red. On the east side of the hill the Old Red Sandstone was regularly overlapped by granite, the strata of the Old Red dipping under it at an angle of 32 degrees. The well-known vitrified fort on the top of the hill contains both rocks highly vitrified. To the west of this another hill rises composed at the base of Old Red, and its upper part consisting of conglomerate granite. He called the attention of the Section specially to this conglomerate granite, and to the evidence which the whole district afforded that the granite here was truly irruptive, and not of that hydrothermal origin to which the granites further east have been ascribed. The only conglomerate granite similar to this with which he was acquainted was one that he had visited some years ago at Forkhill, county Armagh, and he called attention, especially of Professor Hull, to the connexions of these beds to the probable origin of a great irruption of granite.

On the Earthquake Districts of Scotland. *By* JAMES BRYCE, *LL.D.*

On the Tidal-Retardation Argument for the Age of the Earth.

By JAMES CROLL, *LL.D., F.R.S., of the Geological Survey of Scotland.*

Many years ago Sir William Thomson demonstrated from physical considerations that the views which then prevailed in regard to geological time and the age of our globe were perfectly erroneous. His two main arguments, as are well known, were, first, that based on the limit to the sun's possible age, and, secondly, that based on the secular cooling of the earth. More recently he has advanced a third argument*, based on tidal retardation. It is well known that, owing to tidal retardation, the rate of the earth's rotation is slowly diminishing, and it is therefore evident that if we go back for many millions of years we reach a period when the earth must have been rotating much faster than now. Sir William's argument is, that had the earth solidified several hundred millions of years ago, the flattening at the poles and the bulging at the equator would have been much greater than we find them to be. Therefore, because the earth is so little flattened, it must have been rotating when it became solid at very nearly the same rate as at present. And as the rate of rotation is becoming slower and slower, it cannot have been so many millions of years back since solidification took place.

A few years ago I ventured to point out† what appeared to be a very obvious objection to the argument, viz. that the influence of subaerial denudation in altering the form of the earth had been entirely overlooked, and as the validity of the objection, as far as I am aware, has never been questioned, I had been induced to believe that the argument referred to had been abandoned. But I find that Professor Tait, in his work on 'Recent Advances in Physical Science,' restates the argument as perfectly conclusive, and makes no reference whatever to my objection. As the subject is one of very considerable importance, I may be permitted again to direct attention to the objection in question, which briefly is as follows:—

It has been proved by a method pointed out a few years ago‡, and which is now generally admitted to be reliable, that the rocky surface of our globe is being lowered on an average, by subaerial denudation, at the rate of about 1 foot in 6000 years. It follows as a consequence from the loss of centrifugal force resulting from the retardation of the earth's rotation, occasioned by the friction of the tidal wave, that the sea-level must be slowly sinking at the equator and rising at the poles. This of course tends to protect the polar regions and expose equatorial regions to subaerial denudation. Now it is perfectly obvious that unless the sea-level at the equator has, in consequence of tidal retardation, been sinking during past ages at a greater rate than 1 foot in 6000 years, it is physically impossible that the form of our globe could have been very much different from what it is at present, whatever may have been its form when it consolidated, because subaerial denudation would have lowered the equator as rapidly as the sea sank. But in equatorial regions the rate of denudation is no doubt much greater than 1 foot in 6000 years, because the rainfall is greater there than in the temperate regions. It has been shown in the papers above referred to that the rate at which a country is being lowered by subaerial denudation is mainly determined, not so much by the character of its rocks as by the sedimentary carrying-power of its river-systems. Consequently, other things being equal, the greater the rainfall the greater will be the rate of denudation.

We know that the basin of the Ganges, for example, is being lowered by denudation at the rate of about 1 foot in 2300 years, and this is probably not very far from the average rate at which the equatorial regions are being denuded. It is therefore evident that subaerial denudation is lowering the equator as rapidly as the sea-level is sinking from loss of rotation, and that, consequently, we cannot infer from the present form of our globe what was its form when it solidified In so far as tidal retardation can show to the contrary, its form, when solidification took place, may have been as oblate as that of the planet Jupiter

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* Trans Glasgow Geol Soc. vol iii, p 1.

† 'Nature,' August 21, 1871, 'Climate and Time,' p. 335.

‡ 'Philosophical Magazine,' May 1868, pp 378-384, February 1867, p 130, 'Climate and Time,' chap xx., Trans. Glasgow Geol Soc. vol iii p. 153.

There is another circumstance which must be taken into account The lowering of the equator by the transference of the materials from the equator to higher latitudes must tend to increase the rate of rotation, or, more properly, it must tend to *lessen* the rate of tidal retardation

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On the Variation in Thickness of the Middle Coal Measures of the Wigan Coal-field By C E De Rance, *F G.S , of H M. Geological Survey.*

From the Arley Mine, the lowest coal-seam of this series, to the Ince-Yard Coal, at Worthington, north of Wigan, the measures are 2200 feet in thickness, thinning 50 feet per mile to the S W to Prescot, where the measures are only 1445 feet in thickness, and 57 feet per mile to the N E towards Burnley, where the measures between the equivalents of these coals are only 1000 feet in thickness—proving the Wigan coal-basin to be not merely a synclinal of subsidence, but one of deposition, the axis of which was shown to have gradually travelled northwards in time from the district of St Helens to a point north of Wigan The importance of arranging colliery sections in a definite geographical direction, and the importance of noting the occurrence of very thin coal-seams and horizons of fire-clay and of seams full of *Anthracosia*, were insisted on as means of identifying equivalent coal-seams across a district Great lateral shifts were shown to have occurred between many of the great N N W. faults which traverse the Wigan district and divide it up into a series of belts.

On Labyrinthodont Remains from the Upper Carboniferous (Gas-Coal) of Bohemia By Dr Anton Fritsch.

The beds of gas-coal which are now being worked at so many localities, both in Europe and America, serve not only to illuminate our chambers, but to throw fresh light upon many branches of palæontological science, for these beds of gas-coal have been found to yield a remarkably fine fauna, especially rich in the remains of Labyrinthodonts, fishes, and insects

During the last five years, I have been so fortunate as to discover in Bohemia two localities which afford us beautifully preserved relics of ancient life thus entombed in the gas-coals

One of these localities is Nyran, near Pilsen, in the western part of Bohemia, the other is Kounová, near Kakonitz, in the north-west of the country

In both of these places the gas-coals are found to be situated on the top of the Coal-measures proper, but beneath the true Permian deposits. The plants of these beds are closely allied in character to those of the Coal-measures, but the animals appear to be of Permian types.

I do not intend upon the present occasion to enter into a full enumeration and description of these interesting fossils, but I take the liberty of submitting to this Section of the British Association series of specimens of casts and of plates of some of these fossils which I have brought to this country for the purpose of comparing them with the similar remains found in the British Coal-fields

The first three plates exhibited contain enlarged drawings of very small Labyrinthodonts of the group called by Prof Huxley Microsauria One of these, not more than one inch (?) long, has the skeleton completely ossified

The fourth and fifth plates are devoted to a large species of *Labyrinthodon* of about 5 feet in length

Among the specimens, the author drew attention to the teeth of a *Ctenodus*, of which species the bony parts of the skull were found preserved

Of the remarkable genus *Diplodus* a lower jaw with teeth served to show that these latter are not, as was formerly supposed, the dermal spines of a Ray.

Among the insect-remains was observed a new species of *Gamsonychus*, specimens of which cover the whole surface of some slabs of the rock. The restored drawing illustrated the enlargement of the seventh pair of appendages in this species into swimming-feet.

The species of *Julus*, called by the author *J. constans*, shows how little the forms of this genus have changed in the interval between Palæozoic and recent times.

The rich materials which are now accumulated in the Museum of Prague will require for their illustration about 30 or 40 plates in the monograph which the author is now preparing on this very interesting vertebrate fauna.

On the Physical Geology and Geological Structure of Foula. By GEORGE A. GIBSON, *M.B., B.Sc. Edinb.*

Taking up, in the first place, the physiographical geology of the island, in connexion with the agencies involved, the paper describes the coast scenery, and dwells upon the contrast between the low and rugged eastern side and the stupendous cliffs which overhang the western sea. This striking difference is shown to be due partly to the superior powers of resistance to weathering evinced by the materials of the sandstone rocks as contrasted with the crumbling schistose masses, and also to the fact that in the former the strata dip away from the cliffs.

The inland features are next taken up in detail. The five hills are found to be on the west side, three of them (Liorafield, the Sneug, and the Kame, which, taken by aneroid, reach 1000, 1250, and 1150 feet over sea-level) forming an axial chain, whilst the other two (Soberly, 650, and the Noup, 700 feet high) are distinct. The last three are noticed as forming precipices from their summits sheer into the sea, and all, except the Noup, which is dome-shaped, as having a conoid outline, the steepest sides of which face the north and east. As the dip is S.S.W., these hills are therefore held to have a contour in accordance with the empirical law, noted above, that the strata dip away from the side which has the steepest slope. The drainage is of course seen to be easterly.

The lithological character of the rock masses is then detailed, along with their architectural features and stratigraphical relations. The eastern side is described as composed of gneiss, very similar to that of Loch Maree, and of mica-schist with intruded veins of granite, having a strike from N.W. to S.E., agreeing therefore with the presumably Laurentian of Scotland; this, however, is not to be regarded as of great significance, on account of the variable strike of similar rocks in Shetland.

The sandstone series is shown to be separated by a fault from the metamorphic rocks, running from N.N.W. by N. to S.S.E. by S., and along which dislocation the rocks are changed into hard quartz rock. There is described an unbroken succession of sandstones and flags for two miles, at an average dip of more than 25°, whose thickness cannot be estimated at less than 4400 feet.

No fossils having been discovered in these rocks, they are then compared in lithological character and position with the other sandstones of Shetland. Differences in composition and texture are pointed out to be due to altered conditions of deposition, the Bressay and Lerwick flags and sandstones belonging, with the Foula beds, to the Old Red Sandstone of the Caithness series.

On the Red Soil of India. By Dr. GILCHRIST.

On the Strata and Fossils between the Borrowdale Series of the Coniston Flags of the North of England. By Prof. HARKNESS, *F.R.S., and* Prof. A. H. NICHOLSON, *M.D.*

On the Upper Limit of the essentially Marine Beds of the Carboniferous System of the British Isles, and the necessity for the establishment of a Middle Carboniferous Group. By Prof. EDWARD HULL, *F.R.S., &c., Director of the Geological Survey of Ireland.*

In this paper the author endeavours to show the equivalent stages throughout the British Isles of the members of the Carboniferous system, and divides the whole into successive stages from A to G, thus:—

Stages	Name	Localities
G	Upper Coal-measures	Lancashire, N. Wales
F	Middle ,,	England, Scotland, Ireland
E	Lower ditto, or Gannister Beds	England, Wales, Ireland
D	Millstone Grit	England, Scotland, Ireland
C	Yoredale beds	England, Lower Coalfield of Scotland, Ireland
B	Carboniferous Limestone	England, Ireland, Calciferous Sandstone of Scotland
A	Lower Carboniferous Slate, grits and conglomerates, Lower Limestone Shale	

These beds are then identified, both by position and palæontological remains, over the whole area and lead to some important results. Rejecting the evidence of fish and plant remains which are inconclusive, the author finds that there is *a strong palæontological distinction between stages E and F*—*the fauna of the one* (E) being essentially marine, that of the other (F) essentially estuarine or freshwater. The lists of species have been extracted from the memoirs of the Geological Survey, the determination being those of the late Professor E. Forbes, Mr. Salter, and Mr. Baily. The author of this paper is responsible for the determination of the stratigraphical position of the beds from which the species have been obtained.

He finds that there are about 53 species of marine genera in stage E (Gannister beds, or Lower Coal-measures)*, of which 33 come up from the Carboniferous limestone but only 4 or 5 pass up into the overlying stage F (Middle Coal-measures) *indicating a strong palæontological break*.

Again, of 8 marine species found at rare intervals in stage F (Middle Coal-measures) 4 are peculiar to this zone, and the remainder are common to it and stage E. The remaining species belong to the genera *Anthracosia*, *Anthracomya*, &c., which some authorities regard as of freshwater origin, others estuarine; they are probably either. These genera pass into stage G.

These differences, together with some of a stratigraphical nature, between stages F and G on the one hand and E, D, C on the other, are so striking that the author submitted that they should be recognized in the classification of the beds, and he proposed to establish a 'Middle Carboniferous' division, to include all the stages from the Yoredale (C) to the Gannister (E) inclusive. This stage would be essentially marine; while the term 'Upper Carboniferous' would be restricted to the stages F and G, which are shown to be estuarine or freshwater. The term Lower Carboniferous would remain as at present, to designate the Carboniferous Limestone and basal beds of the system, stages A and B.

The author has reason to believe, from information supplied by Professor Roemer, of Breslau, that the marine stage E can be identified on the continent, both in Belgium and Germany a band with *Goniatites* and *Aviculopecten* occurring about 100 feet above the base of the Coal Measures, while, as we learn from Geinitz, the mollusks of the Coal-formation generally belong to the genus *Unio* (*Anthracosia*), so that this remarkable division, with its marine fauna, has had a range as wide as the British Isles and Western Europe, and marks the upward limit of the essentially marine conditions of the Carboniferous system.

On a Deep Boring for Coal at Scarle, near Lincoln. Communicated by Professor Edward Hull, *F.R.S.*

This boring was undertaken about two years ago by a small company of Lincolnshire gentlemen under the advice of Mr. J. T. Boot, mining engineer, of Mansfield, from whom I have received information and specimens constantly during the operations, besides having visited the locality in June 1875. The works have been carried out by the Diamond Rock-boring Company, and specimens of the cores were laid on the table.

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* They have since been considerably added to.—February 1877.

The total depth attained up to this time is 2035 feet. The boring commences in the Lower Lias at a spot about 6 miles south-west of the city of Lincoln, and after traversing the Lias, Rhætic, Keuper and Bunter beds, the Upper Permian and Lower Permian, it entered the Carboniferous formation at a depth of 1901 feet, the remainder of the section being in Carboniferous strata.

The general succession is as follows:—

		Depth ft	Thickness ft
Alluvium		10	10
Lower Lias Clay		60	50
Rhætic Beds ?		145 ?	85 ?
Keuper	Marls	706	561
	Lower Sandstone	958	252
Bunter Sandstone		1500	542
Permian	Upper Marls and Magnesian Limestone	1884	384
	Lower Sandstone	1900	16
Carboniferous Beds	Grey grits with plants, shales with small bivalves (*Anthracosia*)	1955	55
	Bluish calcareous shales and earthy limestone	2020	65
	Fine breccia	2024	4
	Chocolate coloured hard clays	2030	6

The temperature at 2000 feet was 79·1, taken with one of Negretti's thermometers supplied by Professor Everett, of Belfast. At a depth of 917 feet a strong feeder of water was encountered in the Lower Keuper Sandstone and a still stronger at 1250 in the Bunter Sandstone when the water rose 4 feet above the ground. This water unquestionably percolates underground from a distance of 10 or 12 miles, where the beds crop out.

This boring is exceedingly interesting as giving the depth of the Carboniferous rocks so far from the borders of the Nottinghamshire coal-field, and as giving the thickness of the overlying formations, but it has (unfortunately for the spirited gentlemen who have undertaken it) not as yet produced any satisfactory results. The Carboniferous beds are of so peculiar a character that I hesitate to attempt to identify them with any particular division of the Carboniferous system. Meanwhile, as the boring is still being prosecuted, it is hoped that specimens of a more definite nature may be brought up.

On Tertiary Basalt-rock Dykes in Scotland. *By* R. L. Jack, *F.G.S.*

On some New Minerals, and on Doubly-refracting Garnets.
By Dr Von Lasaulx.

The writer exhibited specimens of the new mineral which he terms *melanophlogite* in consequence of its peculiarity of becoming black when heated before the blowpipe. It occurs in very small cubic crystals, of pale brown colour, seated on little scalenohedra of calcite which are associated with the sulphur and celestine of Girgenti, in Sicily. According to analyses, melanophlogite contains 86·29 per cent of silica, 7·2 of sulphuric acid, or some acid of the thionic series not yet determined, 2·8 of strontia, 2·86 of water, and small quantities of alumina and ferric oxide. Dr Von Lasaulx also exhibited specimens of his new species *aerinite*, and several microscopic sections of garnets which exhibited double refraction. He entered into an explanation of the causes of such optical irregularities in monometric crystals, and referred them partly to the effects of tension, partly to chemical alteration, and partly to complexity of structure, due to alternations of isotropic and anisotropic minerals. Thus the variety of garnet called colophonite appears to be a mixture of true garnet and idocrase; hence, whilst one part exhibits single refraction, another part shows double refraction.

On the Changes affecting the Southern Extension of the Lowest Carboniferous Rocks. By G. A. Lebour, *F.G.S.*

In Scotland the lowest division of the Carboniferous series consists of the rocks called 'the Calciferous Sandstones' by Maclaren, and usually known in the north of England as "Tuedian." Prof. Geikie has shown that the lower limit of these rocks merges insensibly into the upper portion of the Old Red Sandstone series. In England their upper limit seems to be equally indefinite, and runs in a kind of lateral dovetailing into the lower beds of the Carboniferous Limestone series or "Bernician." It is this merging of Tuedian into Bernician which forms the subject of the paper. Some remarks as to the terminology of the series followed, and also a short account of the higher divisions of the Carboniferous as represented in the north of England, pointing out especially that the mode of deposition *there* was nearly of the same character from the base of the Millstone Grit to the Old Red series, a slight and very gradual change from brackish to purely marine conditions being the only one of a sufficiently marked and important character to be taken into account. The author admits but two Carboniferous divisions—the Upper, consisting of Coal-measures, Gannister beds, and Millstone grit; and the Lower, including the Bernician or Carboniferous Limestone and the Tuedian or Calciferous Sandstones.

On the Parallel Roads of Glen Roy. By J. Macfadzean.

On the Parallel Roads of Glen Roy. By David Milne-Home, *LL.D.*

The object of the author in this paper was to notice the views of Dr. Tyndall given in a Lecture on Glen Roy, delivered in the Royal Institution, London, on 21st June, 1876.

The author thought that Dr. Tyndall had allowed to himself too short a time, viz. only two days, for an examination of the Lochaber district; as in that space it was impossible to see more than a tenth part of the things which should be examined for a solution of the Parallel Roads problem.

Dr. Tyndall had apparently gone to the district with preconceived opinions in favour of the glacier theory to explain how the lakes had been confined. His knowledge of the Swiss glaciers eminently qualified him to see on the spot whatever could be urged in support of that view. But, after all, the result of Dr. Tyndall's inspection had only satisfied him that there was a "*probability*" of the correctness of the glacier theory, though a probability so great as in Dr. Tyndall's opinion to "amount to a practical demonstration of its truth."

To pave the way for the adoption of the glacier theory of lake-barriers, Dr. Tyndall began his lecture by attempting to annihilate what seemed to him the only other explanation worthy of notice, viz. that first suggested by Sir Thos. Dick Lauder, and defended by Mr. Milne-Home, that the lakes were dammed by detrital blockage. He states that this explanation may with safety be "dismissed as incompetent to account for the present condition of Glens Gluoy and Roy."

Dr. Tyndall, however, seems to have supposed that no better support could be given to the detrital theory except what was stated in Sir Thomas Lauder's paper, published about sixty years ago, ignoring altogether what had been advanced in support of the theory by later writers. He, for example, states that the detrital barriers were supposed by Sir Thomas Lauder to have been heaped up by "some unknown convulsion," a view which no one now suggests, and which Sir Thomas himself never entertained.

What is stated in support of the detrital theory is, that a blockage existed at the mouths of the glens, created by the detritus, which then filled the valleys, and which reached even to the mountain tops at heights of nearly 2500 feet above the sea. Dr. Tyndall admits the abundance of detritus at these heights, and even allows that the Parallel Roads were formed on the detritus.

Glen Collarig shows that the barrier there must have been only 700 or 800 yards in length and about 300 feet in height, as the lakes in that Glen must have been separated by a blockage of these dimensions

Dr Tyndall alleges that all the glens on the south side of Glen Spean were filled with ice whilst those on the north side were filled with water But so far from there being evidence of these valleys being filled with ice, it appears that they also were occupied by lakes, the traces of which are still visible in old beach lines.

Even if there had been glaciers in Glens Treig and N Eoin, as suggested by Mr Jameson, it would have been impossible for these glaciers to have protruded tongues long enough to have reached the places in Glens Roy and Collarig where barriers are required to have been

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On High level Terraces in Carron Valley, County of Linlithgow
By David Milne Home, *LL D*

The river Carron runs into the Frith of Forth near Grangemouth The principal tributary is the Bonny

The whole of that district situated to the east of the Kilsyth and Gargunnoch hills is covered with deep beds of gravel and sand The sand occurs in beds, mostly stratified and generally horizontal

No marine fossils have been found in those drift-beds, but the great probability is that they are marine

The first set of terraces occur at a height of about 140 to 150 feet above the sea Flats at that height occur on both sides of the valley some miles west of Falkirk, these flats slope towards the eastward, *i e* towards the sea, so that near Grangemouth they very little exceed 50 or 60 feet above the sea

Terraces at a height of from 140 to 150 feet occur also in the upper parts of the Carse of Stirling

The second set of terraces occurs only along the banks of the rivers, and is at a height in the Carron of about 35 feet, and in the Bonny of about 29 feet above the present course of these rivers

It is presumable that these haughs were formed when the Carron ran in a channel about 27 feet above its present level, and when the Bonny ran about 28 feet above its present level

The formation of these haughs indicates that the rivers had run permanently in channels at that height The sea therefore, in sinking, had paused in the process, and had stood at a height of about 24 or 25 feet above the present level

This inference is confirmed by the fact of there being traces of an old sea-beach at about that height visible along the coast of the Frith of Forth

The pebbles in the gravel-beds of the district are generally fragments of the hard porphyry rocks of the Gargunnoch and Kilsyth hills, situated to the westward They could have come from no other quarter

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On the Bagshot Peat-Beds *By* W S Mitchell, *LL.B.*

On Circinnate Vernation of Sphenopteris affinis *from the Earliest Stage to Completion, and on the Discovery of* Staphylopteris, *a Genus new to British Rocks* *By* C W Peach, *A.L.S*

The author stated that he had met with *Sphenopteris affinis* in the Carboniferous "blaes" (shales) of an oil-shale pit at West Calder, near Edinburgh, in circinnate vernation, and with it a curious form, apparently a *Staphylopteris* (?), new to British rocks Several species of this new genus have been found in Carboniferous rocks by the officers of the Geological Survey of Illinois and Arkansas, in America, these are figured and described by Leo Lesquereux in the Geological Transactions of those States The author stated that his differed from all these, and thus, until more is known about the British one, he had provisionally given it their generic name.

On the Mountain Limestone of the West Coast of Sumatra. *By* Dr. F. Romer.

On the Raised Beach on the Cumberland Coast, between Whitehaven and Bowness. *By* R. Russell, *C.E.*, *F.G.S.*, *and* T. V. Holmes, *F.G.S.*, *H.M. Geological Survey, England and Wales.*

On the coast of Cumberland between Workington and Bowness the remains of an old sea beach can be most distinctly followed, and south from the former place there is abundant evidence to show that the elevation of the land marked by this raised beach affected the whole of this portion of the west coast of Cumberland.

The characteristic appearance which the raised beach presents is a flat of greater or less width stretching inland—in some cases terminating at the base of a cliff, and in other instances bounded by a flat from 4 to 5 feet below the level of the surface-gravel of this old beach.

North of Workington we have an example of the former case, and at Silloth an instance of the latter.

The surface of this flat is covered with a number of ridges approximately parallel to the coast line and to each other, and these ridges consist of sand and gravel partially covered at various places along the coast with blown sand. This ridgy appearance is seen to be exactly like that portion of the present beach lying between the levels of the highest spring- and the highest neap tides, where small ridges of gravel are observed to be thrown up at the various different levels to which the tide flows in the interval between the two periods above referred to. Typical examples characteristic of littoral deposits are seen at Workington, Harrington, St. Bees, and at numerous places along the coast.

The general resemblance between this upper terrace and the present beach, even in the absence of marine shells in the former, shows that the process of formation in both cases must have been the same.

On the coast between Workington and Whitehaven it exists in small isolated patches, as at the north end of the ridge at Chapel Hill, at Harrington, at Parton, and at Whitehaven. From Workington northwards through Maryport to Brown Rigg the line of an old sea cliff is for the most part very distinctly marked, at the base of which occurs a flat of from 10 chains to 2 chains in breadth; at Allonby this flat is bounded by a gravel or shingle ridge; while from Silloth north to Grune Point, and across Moricambe Bay, from Anthorn to the Solway Viaduct, the country on the east of the old beach consists of a loamy plain, several feet below the level of this beach, from 3 to 4 miles broad, and dotted here and there with a few patches of sand and gravel.

The height of the raised beach is from 20 to 25 feet, rarely exceeding 30 feet above the present sea level. However the base of the old sea-cliff from Oyster Bank to Totter Gill, north of Workington, is about 40 feet above mean sea-level, and there is no distinctive cliff marking a 25-feet beach; it would therefore seem that after the first upheaval the elevation continued to take place very gradually until 40 feet was attained, the beginning of the period of elevation being indicated by the level of the land at the base of this cliff, and its close by the present sea level.

A consideration of the evidence to be obtained from Roman camps and other remains along the coast seems to confirm the conclusion arrived at by Mr. Milne-Home in regard to the latest elevation of the land on the Scotch coasts, viz. that it was prior to the Roman occupation of this country.

Notes on the Drifts and Boulders of the upper part of the Valley of the Wharfe, Yorkshire. *By* Rev. E. Sewell, *M.A.*, *F.G.S.*, *F.R.G.S.*

It is evident that the Wharfe valley in many places must once have been filled up to a certain height with gravelly drift and boulder-clays, containing a very large quantity of Millstone-grit blocks, and that since then the river has excavated a channel in the drift to the depth, in many places, of at least 150 feet.

Now if we suppose the gravelly drift to have been deposited by the river Wharfe, this must have taken place after the Glacial period, as it is clearly of newer date than the two boulder-clays. It would follow that the longitudinal slope of the river-course and other conditions must first have been favourable to deposition, and that afterwards the conditions changed, so as to enable the river to commence that process of denudation, or carrying away, which is still going on.

While, however, it is somewhat difficult to conceive of postglacial changes so great as these, necessitated by this theory of the fluviatile origin of the gravels, we have no clear evidences of such changes having occurred since the final emergence of the land above the glacial sea.

The rival theory that the gravels were deposited by the sea during the gradual rise in the land accounts for their pell-mell and varied character, and for the existence of boulders lying at all angles. The latter may have been dropped from floating ice which may still have lingered on the surface of the sea.

At a considerable elevation above the channels of the Aire and Wharfe, and where there is little or no clay or gravel, many angular and subangular boulders of limestone may be seen resting on Millstone-grit. They have chiefly been transported from between the north and west, and in many instances they would appear to have crossed the intervening valleys and ridges. Mr Mackintosh mentions two limestone erratics near the south-west corner of Embsay Moor, at an altitude of about 1100 feet above the sea. They may likewise be seen on Barden Moor, and a large number have been found at Barden Reservoir, about one mile south-west of Barden Tower. A few small fragments of limestone may be found resting on the Millstone-grit of Rombolds Moor, south of Ilkley, at a height of at least 1100 feet above the sea.

On the east side of the Wharfe valley, near "Appletreewick," there is a hill, consisting of Millstone-grit, called Symonds Seat (marked in the Ordnance Map Earls Seat). On the side of this hill limestone fragments, which must have come from the west or north-west, may be traced up to a height of 1200 feet above the sea, but not to a greater height, as I lately ascertained.

At High Skyreholme, or Trollas Ghyll, about a mile to the north of this hill, are found a most interesting series of limestone-ravines, ranging east, north-east, and south-east, whose almost perpendicular sides rise 300 feet, their summits being not less than 150 yards distance from each other, 1200 feet above the level of the sea. On their rugged bottoms are scattered vast numbers of huge blocks of Millstone-grit in all directions.

The whole of this district is, geologically, exceedingly interesting.

The author believes it may now be regarded as a fact there are no erratics on the eastern slope of the north Pennine Hills in the district under notice at a greater height above the sea than 1200 feet. On the western slope it is well known that they have reached a considerably greater altitude.

On the Upper Silurian Rocks of Lesmahagow. *By* Dr. R. SLIMON.

On the Age, Fauna, and Mode of Occurrence of the Phosphorite Deposits of the South of France. *By* J. E. TAYLOR, *F.G.S.*

On Ridgy Structure in Coal, with Suggestions for accounting for its Origin. *By* Prof. JAMES THOMSON, *F.R.S.E.*

Further Illustrations of the Jointed Prismatic Structure in Basalts and other Igneous Rocks. *By* Prof. JAMES THOMSON, *F.R.S.E.*

On certain pre-Carboniferous and Metamorphosed Trap-dykes and the Associated Rocks of North Mayo, Ireland. By William A. Traill, *M.A.I., F.R.G.S.I., H.M. Geological Survey of Ireland.*

The author first described the locality in North Mayo lying between Downpatrick Head and Broad Haven, and referred to the geological map of Sir Richard Griffith.

The physical features presented precipitous coast sections at Keady Point 372 feet high, and at Benwee Head 829 feet high, in bold and perpendicular headlands.

The geological formations comprising the older or metamorphic rocks lying to the westward consist of flaggy quartzites and micaceous schists, often much contorted and overlapped. The newer or Carboniferous rocks extending from the Glenglassera river eastward, with a primary dip E.N.E. at low angles, comprise white, yellow, and red sandstones, with green and red shales, and limestone bands and beds further eastward.

These Lower Carboniferous sandstones rest unconformably on the metamorphic rocks, which is best seen along one side of a fault at Fohernadeevaun, at the mouth of the Glenglassera river. The basal bed of the Carboniferous strata is a conglomerate of from 1 to 4 feet in thickness, merging into the overlying sandstone beds.

With all due deference to the author of the geological map referred to, the presence of the band of Devonian rocks, as there represented intermediate between the metamorphic and Carboniferous rocks, was called in question and regarded as not existing in that locality.

The intrusive igneous rocks of the district, though much resembling each other, and both belonging to the basaltic type, were shown to belong to two distinct epochs with regard to their time of formation, and also to possess characteristic distinctions.

The older set are undoubtedly of pre-Carboniferous age, as unmistakable fragments are found in the basal conglomerate of the Carboniferous rocks, and they seem to have existed before and to have been metamorphosed with those beds among which they had been intruded. They largely penetrate the metamorphic rocks, but are not found within the area of the Carboniferous strata. They occur chiefly in sheet-like dykes up to 150 feet in thickness, and are often contorted with the beds they penetrate, though apparently the cause of some of the minor crumplings. They are seldom hexagonal, spheroidal, or amygdaloidal in structure.

As examples of these, specimens were exhibited and detailed descriptions given of dykes on Benmore and Glencalry, at Belderg Harbour, and Laghtmurragha, showing the effects of the metamorphic action upon them, viz. the change from a hard splintery microcrystalline basalt towards the centre, to a fibrous hornblendic schistose rock, with soft green chlorite and nests of green chloritic mica, the exterior becoming very schistose, platy, and micaceous, resembling a mica-schist; in part, these might be considered diabases. The felspar is plagioclastic and has a characteristic white weathering in crystalline mottlings through the greenish base.

The adventitious minerals frequently present are mica, chlorite, epidote, garnets, hornblende, quartz, calcite, varieties of felspar, and iron pyrites.

The newer set, or post-Carboniferous dykes, are probably of Tertiary age, and seem to fill cracks or fissures or lines of faults. They are basalts mostly in vertical dykes, and always cut the sheet-like dykes, and are frequently hexagonal, spheroidal, or amygdaloidal in structure, and usually bear W.N.W. and E.S.E., and seldom exceed 25 feet in width. By their decomposing they separate many of the small islands from their respective headlands by narrow precipitous gullies, or form chasms into the cliffs: one of these clefts has vertical walls over 450 feet high, and in part does not exceed some 10 feet in width; this same fissure also cuts off some four islands from their adjacent headlands, the view down which is almost unique.

On the Sub-Wealden Exploration. By H. Willett, *F.G.S.*

Recent Researches into the Organization of some of the Plants of the Coal-measures. By Professor W. C. WILLIAMSON, *F.R.S.*

In bringing the subject before the Geological Section the author chiefly aimed at demonstrating the structural identity of *Calamites* and *Calamodendron* and of *Lepidodendron* and *Sigillaria*. The stems of *Calamites* described in his first memoir published in the 'Philosophical Transactions' were very young ones, in which the highly distinctive Calamitean organization was well preserved, and in one of which the vascular cylinder, composed of a ring of detached woody wedges, was enclosed in a thin parenchymatous undifferentiated bark. He now exhibited a series of specimens, beginning with one less than $\frac{1}{16}$ inch in diameter, in which the vascular cylinder was represented by little more than a circle of the canals, one of which is located at the inner angle of each vascular wedge, and in which the bark was thin undifferentiated parenchyma. From this starting point, the author passed through a series of intermediate examples up to one in which a large pith was surrounded by a cylinder of vessels having a circumference of 15 inches, and which in turn was enclosed within a bark 2 inches in thickness. The outer portions of the vascular cylinder had lost most of the special arrangements of its tissues so characteristic of young stems, which were now modified into a mass of thin radiating vascular wedges, separated by equally thin medullary rays, the condition being almost identical at the nodes and at the internodes. The bark also is now differentiated into two layers, an inner parenchyma and a thick outer prosenchyma, the cells of the latter assuming the prismatic type. There is little or no doubt that externally to this the living plant possessed at least a third layer of parenchyma not preserved in the author's specimen.

A series of sections was then exhibited, demonstrating the erroneousness of Brongniart's distinction between *Lepidodendron* and *Sigillaria*. The author had previously pointed this out in the case of the *Lepidodendra* characteristic of the lowermost Carboniferous rocks obtained from the Burntisland deposit. He now showed that it was equally true of the common *L. selaginoides* of the Upper Coal-measures, whilst *L. harcourtii* has only the structure long ago described by Brongniart, viz. an inner vascular cylinder not developed exogenously. All the other *Lepidodendra* referred to possess an outer exogenous cylinder such as Brongniart believed to be characteristic of *Sigillaria*, and which exists in the *Anabathra* of Witham and the *Diploxylon* of Corda. The author thus concludes that the *Lepidodendron harcourtii* represents the lowest degree of development seen amongst the *Lepidodendra*, as *Sigillaria* exhibited the highest, whilst the *Lepidodendron selaginoides* of the Middle Coal-measures occupies an intermediate position.

On the Junction of Granite and Old Red Sandstone at Corrie and Glen Sannox, Arran. By E. A. WÜNSCH, *F.G.S.*

The object of this paper is to show by specimens and diagrams that the rock intervening between the granite and the stratified rocks on the north-east coast of Arran is not, as held by Professor Ramsay and Dr. Bryce, a band of slate. There is no slate in all Glen Sannox, nor as far south as Brodick Castle. The sedimentary rocks, Old Red and Carboniferous, cropping upon the shore, retain in a remarkable manner the same general dip, the initial direction of which is given to them by the great anticlinal axis of mid Sannox, and abut right against the granitic nucleus of the island.

As we approach the junction, at a height of about 800 feet from the sea-level, the angle of inclination becomes more highly inclined, and the hitherto clearly stratified beds assume a granitoid structure.

At the point of contact the Old Red Sandstone is so altered as to resemble slate, and was mistaken for such and circumstantially mapped down as an extensive band of slate by Dr. Bryce; but no one can mistake the real character of the rock if he begin his examination in the bed of the burn, about 60 yards below the junction, where the Old Red Sandstone is seen exposed in its unaltered state, finegrained and of the usual deep red colour, dipping S.E at an angle of about 45°, and starting from this point the gradually altered character of the rock becomes apparent every few yards as we proceed towards the junction

The first appearance of change is shown in a series of chocolate-coloured rocks with greenish veins and streaks traversing them, and as these become more indurated they turn lighter in colour, and take on a beautifully mottled appearance, closely resembling variegated marble, and finally, within a few yards of the junction, the rock turns dark grey or almost black The actual contact is beautifully seen on the almost perpendicular face of the rock, under a waterfall formed by the small burn flowing over the lip of the Corrie south of the grand peak of Ciod-na-oigh.

Identically the same appearances are observed when ascending up to the granite in the bed of the "White Water," the falls of which form a conspicuous landmark on the hillside above Corrie.

The author made these two points typical, and his specimens and diagrams referred to them, but numerous other sections are laid bare in the small burns and ravines intersecting the hillside, and bear out the same conclusions

The author showed a diagram from Corrie to the White Water, showing that if it were not for the extensive denudation that has taken place we should probably see the Carboniferous rocks abutting against the granite, as they must originally have done He also gave an enlarged copy of Dr Bryce's map of the localities referred to, accompanied by a duplicate map of the same localities and on the same scale, with the supposed slate replaced by the Old Red Sandstone. In Glen Sannox burn the junction appears to take place by contact of the granite with the massive Old Red conglomerate, and he was able to exhibit specimens quarried out of the bed of the burn showing large rounded quartz pebbles in a state of semifusion and the matrix of the rock traversed by alternate black bands and streaks and white semigranitic veins and patches, but though the actual junction must be within a few yards of the spot where he quarried, he was unable to lay it bare, owing to the deep water and the mass of gravel and sand in the bed of the burn.

He also mentioned that everywhere at the point of contact with the Old Red Sandstone the granite is delicately mottled or clouded (as shown by his polished specimens), as if the black film of the absorbed mass had remained floating and become fixed in the white pasty mass. And this appearance he holds is in itself sufficient to point to a junction of granite with rock other than slate, for though innumerable instances may be seen in other parts of the island of junctions of granite with true slate, in not a single instance is the adjoining granite affected in this particular manner.

On Siliceous Sponges from the Carboniferous Limestone near Glasgow.
By JOHN YOUNG, *F.G.S.*

The author exhibited a series of mounted specimens of sponge-spicula recently obtained from a deposit of rotted limestone filling fissures in the Carboniferous Limestone series at Cunningham Bedland, near Dalry, Ayrshire. He stated that the discovery of the spicules was due to the investigation of the deposit by Mr. John Smith, of the Geological Society of Glasgow. He was not aware of similar sponge-spicules having been found in any other Carboniferous Limestone district within the British Isles, and their abundant occurrence in this deposit testified to the existence of sponges with large siliceous spicula over this tract of the Scottish Carboniferous sea-bottom.

BIOLOGY.

Address by ALFRED RUSSEL WALLACE, *F.R.G.S., F.L.S., President of the Section.*

THE range of subjects comprehended within this Section is so wide, and my own acquaintance with them so imperfect, that it is not in my power to lay before you any general outline of the recent progress of the biological sciences. Neither do I feel competent to give you a summary of the present status of any one of the great divisions of our science, such as Anatomy, Physiology, Embryology, Histology, Classification, or Evolution—Philology, Ethnology, or Prehistoric Archæology, but there are fortunately several outlying and more or less neglected subjects to which I have for some time had my attention directed, and which I hope will furnish matter for a few observations of some interest to biologists, and be at the same time not unintelligible to the less scientific members of the Association who may honour us with their presence.

The subjects I first propose to consider have no general name, and are not easily grouped under a single descriptive heading, but they may be compared with that recent development of a sister science which has been termed Surface-geology or Earth-sculpture. In the older geological works we learnt much about strata, and rocks, and fossils, their superposition, contortions, chemical constitution, and affinities, with some general notions of how they were formed in the remote past, but we often came to the end of the volume no whit the wiser as to how and why the surface of the earth came to be so wonderfully and beautifully diversified; we were not told why some mountains are rounded and others precipitous, why some valleys are wide and open, others narrow and rocky; why rivers so often pierce through mountain-chains, why mountain lakes are often so enormously deep, whence came the gravel, and drift, and erratic blocks so strangely spread over wide areas while totally absent from other areas equally extensive. So long as these questions were almost ignored, geology could hardly claim to be a complete science, because, while professing to explain how the crust of the earth came to be what it is, it gave no intelligible account of the varied phenomena presented by its surface. But of late years these surface-phenomena have been assiduously studied, the marvellous effects of denudation and glacial action in giving the final touches to the actual contour of the earth's surface, and their relation to climatic changes and the antiquity of man, have been clearly traced, thus investing geology with a new and popular interest, and at the same time elucidating many of the phenomena presented in the older formations.

Now just as a surface-geology was required to complete that science, so a surface-biology was wanted to make the science of living things more complete and more generally interesting, by applying the results arrived at by special workers to the interpretation of those external and prominent features whose endless variety and beauty constitute the charm which attracts us to the contemplation or to the study of nature. The descriptive zoologist, for example, gives us the external characters of animals; the anatomist studies their internal structure, the histologist makes known to us the nature of their component tissues, the embryologist patiently watches the progress of their development, the systematist groups them into classes and orders, families, genera, and species, while the field-naturalist studies for us their food and habits and general economy. But till quite recently none of these earnest students, nor all of them combined, could answer satisfactorily, or even attempted to answer, many of the simplest questions concerning the external characters and general relations of animals and plants. Why are flowers so wonderfully varied in form and colour? what causes the Arctic fox and the ptarmigan to turn white in winter? why are there no elephants in America and no deer in Australia? why are closely allied species rarely found together? why are male animals so frequently bright-coloured? why are extinct animals so often larger than those which are now living? what has led to the production of the gorgeous train of the peacock and of the two kinds of flower in the primrose? The solution of these and a hundred other problems of like nature was rarely approached by the old method of study, or if approached was only the subject of vague speculation. It is to the illustrious author of the 'Origin of Species' that we are indebted for teaching us how to study nature as one great, compact, and beautifully adjusted system. Under the touch of his magic wand the countless isolated facts of internal and external structure of living things—their habits, their colours, their development, their distribution, their geological history,—all fell into their approximate places, and although, from the intricacy of the subject and our very imperfect knowledge of the facts themselves, much still remains uncertain, yet we can no longer doubt that even the minutest and most superficial peculiarities of animals and plants either, on the one hand, are or have been useful to them, or, on the other hand, have been developed under the influence of general laws, which we may one day understand to a much greater extent than we do at present. So great is the alteration effected in our comprehension of nature by the study of variation, inheritance, cross-breeding, competition, distribution, protection, and selection—showing, as they often do, the meaning of the most obscure phenomena and the mutual dependence of the most widely-separated organisms—that it can only be fitly compared with the analogous alteration produced in our conception of the universe by Newton's grand discovery of the law of gravitation.

I know it will be said (and is said) that Darwin is too highly rated, that some of his theories are wholly and others partially erroneous, and that he often builds a vast superstructure on a very uncertain basis of doubtfully interpreted facts. Now, even admitting this criticism to be well founded—and I myself believe that to a limited extent it is so—I nevertheless maintain that Darwin is not and cannot be too highly rated; for his greatness does not at all depend upon his being infallible, but on his having developed, with rare patience and judgment, a new system of observation and study, guided by certain general principles which are almost as simple as gravitation and as wide-reaching in their effects. And if other principles should hereafter be discovered, or if it be proved that some of his subsidiary theories are wholly or partially erroneous, this very discovery can only be made by following in Darwin's steps, by adopting the method of research which he has taught us, and by largely using the rich stores of material which he has collected. The 'Origin of Species,' and the grand series of works which have succeeded it, have revolutionized the study of biology; they have given us new ideas and fertile principles, they have infused life and vigour into our science, and have opened up hitherto unthought-of lines of research on which hundreds of eager students are now labouring. Whatever modifications some of his theories may require, Darwin must none the less be looked up to as the founder of philosophical biology.

As a small contribution to this great subject, I propose now to call your attention to some curious relations of organisms to their environment, which seem to me worthy of more systematic study than has hitherto been given them. The points I shall more especially deal with are—the influence of locality, or of some unknown local causes, in determining the colours of insects, and, to a less extent, of birds, and the way in which certain peculiarities in the distribution of plants may have been brought about by their dependence on insects. The latter part of my address will deal with the present state of our knowledge as to the antiquity and early history of mankind.

On some Relations of Living Things to their Environment.

Of all the external characters of animals, the most beautiful, the most varied, and the most generally attractive are the brilliant colours and strange yet often elegant markings with which so many of them are adorned. Yet of all characters this is the most difficult to bring under the laws of utility or of physical connexion. Mr. Darwin—as you are well aware—has shown how wide is the influence of sex on the intensity of coloration, and he has been led to the conclusion that active or voluntary sexual selection is one of the chief causes, if not the chief cause, of all the variety and beauty of colour we see among the higher animals. This is one of the points on which there is much divergence of opinion even among the supporters of Mr Darwin, and one as to which I myself differ from him. I have argued, and still believe, that the need of protection is a far more efficient cause of variation of colour than is generally suspected; but there are evidently other causes at work, and one of these seems to be an influence depending strictly on locality, whose nature we cannot yet understand, but whose effects are everywhere to be seen when carefully searched for.

Although the careful experiments of Sir John Lubbock have shown that insects can distinguish colours—as might have been inferred from the brilliant colours of the flowers which are such an attraction to them—yet we can hardly believe that their appreciation and love of distinctive colours is so refined as to guide and regulate their most powerful instinct—that of reproduction. We are therefore led to seek some other cause for the varied colours that prevail among insects; and as this variety is most conspicuous among butterflies—a group perhaps better known than any other—it offers the best means of studying the subject. The variety of colour and marking among these insects is something marvellous. There are probably about ten thousand different kinds of butterflies now known, and about half of these are so distinct in colour and marking that they can be readily distinguished by this means alone. Almost every conceivable tint and pattern is represented; and the hues are often of such intense brilliance and purity as can be equalled by neither birds nor flowers.

Any help to a comprehension of the causes which may have concurred in bringing about so much diversity and beauty must be of value; and this is my excuse for laying before you the more important cases I have met with of a connexion between colour and locality.

Our first example is from tropical Africa, where we find two unrelated groups of butterflies belonging to two very distinct families (Nymphalidæ and Papilionidæ) characterized by a prevailing blue green colour not found in any other continent.* Again, we have a group of African Pieridæ which are white or pale yellow with a marginal row of bead-like black spots; and in the same country one of the Lycænidæ (*Leptena erastus*) is coloured so exactly like these that it was at first described as a species of *Pieris*. None of these four groups are known to be in any way specially protected, so that the resemblance cannot be due to protective mimicry.

In South America we have far more striking cases; for in the three subfamilies *Danainæ*, *Acræinæ*, and *Heliconinæ*, all of which are specially protected, we find identical tints and patterns reproduced, often in the greatest detail, each peculiar type of coloration being characteristic of distinct geographical subdivisions of the continent. Nine very distinct genera are implicated in these parallel changes—*Lycorea*, *Ceratinia*, *Mechanitis*, *Ithomia*, *Melinæa*, *Tithorea*, *Acræa*, *Heliconius*, and *Eueides*, groups of three or four (or even five) of them appearing together in the same livery in one district, while in an adjoining district most or all of them undergo a simultaneous change of coloration or of marking. Thus in the genera *Ithomia*, *Mechanitis*, and *Heliconius* we have species with yellow apical spots in Guiana, all represented by allied species with white apical spots in South Brazil. In *Mechanitis*, *Melinæa*, and *Heliconius*, and sometimes in *Tithorea*, the species of the Southern Andes (Bolivia and Peru) are characterized by an orange and black livery, while those of the Northern Andes (New Granada) are almost always orange-yellow and black. Other changes of a like nature, which it would be tedious to enumerate, but which are very striking when specimens are examined, occur in species of the same groups inhabiting these same localities, as well as Central America and the Antilles. The resemblance thus produced between widely different insects is sometimes general, but often so close and minute that only a critical examination of structure can detect the difference between them. Yet this can hardly be true mimicry, because all are alike protected by the nauseous secretion which renders them unpalatable to birds.

In another series of genera (*Catagramma*, *Callithea*, and *Agrias*), all belonging to the Nymphalidæ, we have the most vivid blue ground, with broad bands of orange-crimson or a different tint of blue or purple, exactly reproduced in corresponding, yet unrelated species, occurring in the same locality; yet, as none of these groups are protected, this can hardly be true mimicry. A few species of two other genera in the same country (*Eunica* and *Siderone*) also reproduce the same colours, but with only a general resemblance in the marking. Yet, again, in Tropical America we have species of *Apatura* which, sometimes in both sexes, sometimes in the female only, exactly imitate the peculiar markings of another genus (*Heterochroa*) confined to America. here, again, neither genus is protected, and the similarity must be due to unknown local causes.

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* *Romaleosoma* and *Euryphene* (Nymphalidæ), *Papilio zalmoxis* and several species of the *Nireus*-group (Papilionidæ).

But it is among islands that we find some of the most striking examples of the influence of locality on colour, generally in the direction of paler, but sometimes of darker and more brilliant hues, and often accompanied by an unusual increase of size. Thus in the Moluccas and New Guinea we have several Papilios (*P. euchenor*, *P. ormenus*, and *P. tydeus*) distinguished from their allies by a much paler colour, especially in the females, which are almost white. Many species of *Danais* (forming the subgenus *Ideopsis*) are also very pale. But the most curious are the Euplœas, which in the larger islands are usually of rich dark colours, while in the small islands of Banda, Ké, and Matabello at least three species not nearly related to each other (*E. hopfferi*, *E. euripon*, and *E. assimilata*) are all broadly banded or suffused with white, their allies in the larger islands being all very much darker. Again, in the genus *Diadema*, belonging to a distinct family, three species from the small Aru and Ké islands (*D. deois*, *D. hewitsonii*, and *D. polymena*) are all more conspicuously white-marked than their representatives in the larger islands. In the beautiful genus *Cethosia*, a species from the small island of Waigiou (*C. cyrene*) is the whitest of the genus. *Prothoe* is represented by a blue species in the continental island of Java, while those inhabiting the ancient insular groups of the Moluccas and New Guinea are all pale yellow or white. The genus *Drusilla*, almost confined to these islands, comprises many species which are all very pale, while in the small island of Waigiou is found a very distinct genus, *Hyantis*, which, though differing completely in the neuration of the wings, has exactly the same pale colours and large ocellated spots as *Drusilla*. Equally remarkable is the fact that the small island of Amboina produces larger-sized butterflies than any of the larger islands which surround it. This is the case with at least a dozen butterflies belonging to many distinct genera*, so that it is impossible to attribute it to other than some local influence. In Celebes, as I have elsewhere pointed out†, we have a peculiar form of wing and much larger size running through a whole series of distinct butterflies, and this seems to take the place of any speciality in colour.

From the Fiji Islands we have comparatively few butterflies, but there are several species of *Diadema* of unusually pale colours, some almost white.

The Philippine Islands seem to have the peculiarity of developing metallic colours. We find there at least three species of *Euplœa*‡ not closely related, and all of more intense metallic lustre than their allies in other islands. Here also we have one of the large yellow *Ornithopteræ* (*O. magellanus*), whose hind wings glow with an intense opaline lustre not found in any other species of the entire group, and an *Adolias*§ is larger and of more brilliant metallic colouring than any other species in the archipelago. In these islands also we find the extensive and wonderful genus of weevils (*Pachyrhynchus*), which in their brilliant metallic colouring surpass any thing found in the whole eastern hemisphere, if not in the whole world.

In the Andaman Islands in the Bay of Bengal there are a considerable number of peculiar species of butterflies differing slightly from those on the continent, and generally in the direction of paler or more conspicuous colouring. Thus two species of *Papilio* which on the continent have the tails black, in their Andaman representatives have them either red- or white-tipped‖. Another species¶ is richly blue-banded where its allies are black, while three species of distinct genera of

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* *Ornithoptera priamus*, *O. helena*, *Papilio deiphobus*, *P. ulysses*, *P. gambrisius*, *P. codrus*, *Iphias leucippe*, *Euplœa prothoé*, *Hestia idea*, *Athyma jocaste*, *Diadema pandarus*, *Nymphalis pyrrhus*, *N. euryalus*, *Drusilla jairus*.

'Contributions to the Theory of Natural Selection,' pp. 168–173.

Euplœa hewitsonii, *E. diocletiana*, *E. lætifica*.

Adolias calliphorus.

Papilio rhodifer (near *P. doubledayi*) and *Papilio charicles* (near *P. memnon*).

Papilio mayo.

Nymphalidæ* all differ from their allies on the continent in being of excessively pale colours as well as of somewhat larger size.

In Madagascar we have the very large and singularly white-spotted *Papilio antenor*, while species of three other genera† are very white or conspicuous compared with their continental allies.

Passing to the West Indian Islands and Central America (which latter country has formed a group of islands in very recent times) we have similar indications. One of the largest of the Papilios inhabits Jamaica,‡ while another, the largest of its group, is found in Mexico.§ Cuba has two of the same genus whose colours are of surpassing brilliancy;|| while the fine genus *Clothilda*—confined to the Antilles and Central America—is remarkable for its rich and showy colouring.

Persons who are not acquainted with the important structural differences that distinguish these various genera of butterflies can hardly realize the importance and the significance of such facts as I have now detailed. It may be well, therefore, to illustrate them by supposing parallel cases to occur among the Mammalia. We might have, for example, in Africa the gnus, the elands, and the buffaloes, all coloured and marked like zebras, stripe for stripe over the whole body exactly corresponding. So the hares, marmots, and squirrels of Europe might be all red with black feet, while the corresponding species of Central Asia were all yellow with black heads. In North America we might have racoons, squirrels, and opossums in parti-coloured livery of white and black so as exactly to resemble the skunk of the same country, while in South America they might be black with a yellow throat patch so as to resemble with equal closeness the tayra of the Brazilian forests. Were such resemblances to occur in anything like the number and with the wonderful accuracy of imitation met with among the Lepidoptera, they would certainly attract universal attention among naturalists, and would lead to the exhaustive study of the influence of local causes in producing such startling results.

One somewhat similar case does indeed occur among the Mammalia, two singular African animals, the Aard-wolf (*Proteles*) and the hyæna-dog (*Lycaon*), both strikingly resembling hyænas in their general form as well as in their spotted markings. Belonging as they all do to the Carnivora, though to three distinct families, it seems quite an analogous case to those we have imagined; but as the Aard-wolf and the hyena-dog are both weak animals compared with the hyæna, the resemblance may be useful, and in that case would come under the head of mimicry. This seems the more probable because, as a rule, the colours of the Mammalia are protective, and are too little varied to allow of the influence of local causes producing any well-marked effects.

When we come to birds, however, the case is different; for although they do not exhibit such distinct marks of the influence of locality as do butterflies—probably because the causes which determine colour are in their case more complex—yet there are distinct indications of some effect of the kind, and we must devote some little time to their consideration.

One of the most curious cases is that of the parrots of the West Indian Islands and Central America, several of which have white heads or foreheads, occurring in two distinct genera,¶ while none of the more numerous parrots of South America are so coloured. In the small island of Dominica we have a very large and richly-coloured parrot (*Chrysotis augusta*) corresponding to the large and richly-coloured *Papilio homerus* of Jamaica.

The Andaman Islands are equally remarkable, at least six of the peculiar birds differing from their continental allies in being much lighter, and sometimes with a large quantity of pure white in the plumage**, exactly corresponding to what occurs among the butterflies.

In the Philippines this is not so marked a feature; yet we have here—the only known white-breasted kingcrow (*Dicrurus mirabilis*), the newly discovered *Eury-*

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* *Euplœa andamanensis*, *Cethosia biblis*, *Cyrestis cocles*.

† *Danais nossima*, *Melanitis massoura*, *Diadema dexithea*.

‡ *Papilio homerus*. § *P. daunus*. || *P. gundlachianus*, *P. villiersi*.

¶ *Pionus albifrons* and *Chrysotis senilis* (C. America), *Chrysotis sallæi* (Hayti).

** *Kittacincla albiventris*, *Geocichla albogularis*, *Sturnia andamanensis*, *Hyloterpe grisola*, var., *Janthœnas palumboides*, *Osmotreron chloroptera*.

Lanius Sterni, wholly white beneath; three species of *Dicæum*, all white beneath; several species of *Parus*, largely white-spotted, while many of the pigeons have light ashy tints. The birds generally, however, have rich dark colours, similar to those which prevail among the butterflies.

In Celebes we have a swallow-shrike and a peculiar small crow allied to the jackdaw [*], whiter than any of their allies in the surrounding islands, but otherwise the colours of the birds call for no special remark.

In Timor and Flores we have white-headed pigeons [†], and a long-tailed fly-catcher almost entirely white [‡].

In the small Lord Howe's Island we have the recently extinct white rail (*Notornis alba*), remarkably contrasting with its allies in the larger islands of New Zealand.

We cannot, however, lay any stress on isolated examples of white colour, since these occur in most of the great continents; but where we find a series of species of distinct genera all differing from their continental allies in a whiter coloration, as in the Andaman Islands and the West Indies, and, among butterflies, in the smaller Moluccas, the Andamans, and Madagascar, we cannot avoid the conclusion that in these insular localities some general cause is at work.

There are other cases, however, in which local influences seem to favour the production or preservation of intense crimson or a very dark coloration. Thus in the Moluccas and New Guinea alone we have bright red parrots belonging to two distinct families [§], and which therefore most probably have been independently produced or preserved by some common cause. Here, too, and in Australia we have black parrots and pigeons [||], and it is a most curious and suggestive fact that in another insular subregion—that of Madagascar and the Mascarene Islands—these same colours reappear in the same two groups [¶].

Some very curious physiological facts bearing upon the presence or absence of white colours in the higher animals have lately been adduced by Dr Ogle [**]. It has been found that a coloured or dark pigment in the olfactory region of the nostrils is essential to perfect smell, and this pigment is rarely deficient except when the whole animal is pure white. In these cases the creature is almost without smell or taste. This, Dr Ogle believes, explains the curious case of the pigs in Virginia adduced by Mr Darwin, white pigs being killed by a poisonous root which does not affect black pigs. Mr Darwin imputed this to a constitutional difference accompanying the dark colour, which rendered what was poisonous to the white-coloured animals quite innocuous to the black. Dr Ogle, however, observes that there is no proof that the black pigs eat the root, and he believes the more probable explanation to be that it is distasteful to them, while the white pigs, being deficient in smell and taste, eat it and are killed. Analogous facts occur in several distinct families. White sheep are killed in the Tarentino by eating *Hypericum crispum*, while black sheep escape; white rhinoceroses are said to perish from eating *Euphorbia candelabrum*, and white horses are said to suffer from poisonous food where coloured ones escape. Now it is very improbable that a constitutional immunity from poisoning by so many distinct plants should, in the case of such widely different animals, be always correlated with the same difference of colour; but the facts are readily understood if the senses of smell and taste are dependent on the presence of a pigment which is deficient in wholly white animals. The explanation has, however, been carried a step further, by experiments showing that the absorption of odours by dead matter, such as clothing, is greatly affected by colour, black being the most powerful absorbent, then blue, red, yellow, and lastly white. We have here a physical cause for the sense-inferiority of totally white animals which may account for their rarity in nature; for few, if any, wild animals are wholly white; the head, the face, or at least the muzzle or the nose, are generally black; the ears and eyes are also often black; and there is reason to believe that dark pigment is essential to good hearing, as it certainly is to perfect vision. We can therefore understand why white cats with blue eyes are so often deaf, a peculiarity we notice more readily than their deficiency of smell or taste.

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[*] *Artamus monachus*, *Corvus advena*.

[†] *Ptilopus cinctus*, *P. albocinctus*.

[‡] *Tchitrea affinis*, var.

[§] *Lorius*, *Eos* (Trichoglossidæ), *Eclectus* (Palæornithidæ).

[||] *Microglossus*, *Calyptorhynchus*, *Turacæna*.

[¶] *Coracopsis*, *Alectrœnas*.

[**] Medico-Chirurgical Transactions, vol. liii. (1870).

If, then, the prevalence of white coloration is generally accompanied with some deficiency in the acuteness of the most important senses, this colour becomes doubly dangerous, for it not only renders its possessor more conspicuous to its enemies but at the same time makes it less ready in detecting the presence of danger. Hence perhaps the reason why white appears more frequently in islands, where competition is less severe and enemies less numerous and varied. Hence also a reason why *albinism*, although freely occurring in captivity, never maintains itself in a wild state, while *melanism* does. The peculiarity of some islands in having all their inhabitants of dusky colours (as the Galapagos) may also perhaps be explained on the same principles, for poisonous fruits or seeds may there abound which weed out all white- or light-coloured varieties owing to their deficiency of smell and taste. We can hardly believe, however, that this would apply to white-coloured butterflies, and this may be a reason why the effect of an insular habitat is more marked in these insects than in birds or mammals. But though inapplicable to the lower animals this curious relation of sense acuteness with colours may have had some influence on the development of the higher human races. If light tints of the skin were generally accompanied by some deficiency in the senses of smell, hearing and vision, the white could never compete with the darker races so long as man was in a very low or savage condition and wholly dependent for existence on the acuteness of his senses. But as the mental faculties became more fully developed and more important to his welfare than mere sense-acuteness, the lighter tints of skin and hair and eyes would cease to be disadvantageous whenever they were accompanied by superior brain power. Such variations would then be preserved, and thus may have arisen the Xanthochroic race of mankind, in which we find a high development of intellect accompanied by a slight deficiency in the acuteness of the senses as compared with the darker forms.

I have now to ask your attention to a few remarks on the peculiar relations of plants and insects as exhibited in islands.

Ever since Mr Darwin showed the immense importance of insects in the fertilization of flowers great attention has been paid to the subject, and the relation of these two very different classes of natural objects has been found to be more universal and more complex than could have been anticipated. Whole genera and families of plants have been so modified as first to attract and then to be fertilized by certain groups of insects, and this special adaptation seems in many cases to have determined the more or less wide range of the plants in question. It is also known that some species of plants can be fertilized only by particular species of insects, and the absence of these from any locality would necessarily prevent the continued existence of the plant in that area. Here, I believe, will be found the clue to much of the peculiarity of the floras of oceanic islands, since the methods by which these have been stocked with plants and insects will be often quite different. Many seeds are, no doubt, carried by oceanic currents, others probably by aquatic birds. Mr H N Moseley informs me that the albatrosses, gulls, puffins, tropic birds, and many others nest inland, often amidst dense vegetation, and he believes they often carry seeds, attached to their feathers, from island to island for great distances. In the tropics they often nest on the mountains far inland, and may thus aid in the distribution even of mountain-plants. Insects, on the other hand, are mostly conveyed by aerial currents, especially by violent gales, and it may thus often happen that totally unrelated plants and insects may be brought together, in which case the former must often perish for want of suitable insects to fertilize them. This will, I think, account for the strangely fragmentary nature of these insular floras, and the great differences that often exist between those which are situated in the same ocean, as well as for the preponderance of certain orders and genera. In Mr Pickering's valuable work on the 'Geographical Distribution of Animals and Plants,' he gives a list of no less than sixty-six natural orders of plants *unexpectedly* absent from Tahiti, or which occur in many of the surrounding lands, some being abundant in other islands—as the Labiatæ at the Sandwich Islands. In these latter islands the flora is much richer, yet a large number of families which abound in other parts of Polynesia are totally wanting. Now much of the poverty and exceptional distribution of the plants of those islands is probably due to the great scarcity of flower-frequenting insects. Lepidoptera and Hymenoptera are exceedingly scarce in the eastern islands of the Pacific, and it is almost certain that many plants which require these insects for their fertilization have been thereby prevented from establishing themselves. In the western islands, such as the Fijis, several species of butterflies occur in tolerable abundance, and no doubt some flower-haunting Hymenoptera accompany them; and in these islands the flora appears to be much more varied, and especially to be characterized by a much greater variety of showy flowers, as may be seen by examining the plates of Dr. Seemann's 'Flora Vitiensis.'

Darwin and Pickering both speak of the great preponderance of ferns at Tahiti; and Mr. Moseley, who spent several days in the interior of the island, informs me that "at an elevation of from 2000 to 3000 feet the dense vegetation is composed almost entirely of ferns. A tree fern (*Alsophila tahitensis*) forms a sort of forest to the exclusion of almost every other tree, and, with huge plants of two other ferns (*Angiopteris evecta* and *Asplenium nidus*), forms the main mass of the vegetation." And he adds, "I have nowhere seen ferns in so great proportionate abundance." This unusual proportion of ferns is a general feature of insular as compared with continental floras, but it has, I believe, been generally attributed to favourable conditions, especially to equable climate and perennial moisture. In this respect, however, Tahiti can hardly differ greatly from many other islands, which yet have no such vast preponderance of ferns. This is a question that cannot be decided by mere lists of species, since it is probable that in Tahiti they are less numerous than in some other islands where they form a far less conspicuous feature in the vegetation. The island most comparable with Tahiti in that respect is Juan Fernandez. Mr. Moseley writes to me:—"In a general view of any wide stretch of the densely clothed mountainous surface of the island, the ferns, both tree ferns and the unstemmed forms, are seen at once to compose a very large proportion of the mass of foliage." As to the insects of Juan Fernandez, Mr. Edwyn C. Reed, who made two visits and spent several weeks there, has kindly furnished me with some exact information. Of butterflies there is only one (*Pyrameis carye*), and that rare—a Chilian species, and probably an accidental straggler. Four species of moths of moderate size were observed (all Chilian), and a few larvæ and pupæ. Of bees there were none, except one very minute species (allied to *Chilicola*), and of other Hymenoptera a single specimen of *Ophion luteus* (a cosmopolitan ichneumon). About twenty species of flies were observed, and these formed the most prominent feature of the entomology of the island.

Now, as far as we know, this extreme entomological poverty agrees closely with that of Tahiti, and there are probably no other portions of the globe equally favoured in soil and climate, and with an equally luxuriant vegetation, where insect-life is so scantily developed. It is curious, therefore, to find that these two islands also agree in the wonderful predominance of ferns over the flowering plants—in individuals even more than in species; and there is no difficulty in connecting the two facts. The excessive minuteness and great abundance of fern-spores causes them to be far more easily distributed by winds than the seeds of flowering plants, and they are thus always ready to occupy any vacant places in suitable localities, and to compete with the less vigorous flowering plants. But where insects are so scarce, all plants which require insect-fertilization, whether constantly to enable them to produce seed at all, or occasionally to keep up their constitutional vigour by crossing, must be at a great disadvantage; and thus the scanty flora which oceanic islands must always possess, peopled as they usually are by waifs and strays from other lands, is rendered still more scanty by the weeding out of all such as depend largely on insect-fertilization for their full development. It seems probable, therefore, that the preponderance of ferns in islands (considered in mass of individuals rather than in number of species) is largely due to the absence of competing phænogamous plants, and that this is in great part due to the scarcity of insects. In other oceanic islands, such as New Zealand and the Galapagos, where ferns, although tolerably abundant, form no such predominant feature in the vegetation, but where the scarcity of flower-haunting insects is almost equally marked, we find a great preponderance of small green, or otherwise inconspicuous flowers, indicating that only such plants have been enabled to flourish there as are independent of insect fertilization. In the Galapagos (which are perhaps even more deficient in flying insects than Juan Fernandez) this is so striking a feature that Mr. Darwin speaks of the vegetation as consisting in great part of "wretched-looking weeds," and states that "it was some time before he discovered that almost every plant was in flower at the time of his visit." He also says that he "did not see one beautiful flower in the islands." It appears, however, that Compositæ, Leguminosæ, Rubiaceæ and Solanaceæ form a large proportion of the flowering plants, and as these are orders which usually require insect-fertilization, we must suppose either that they have become modified so as to be self-fertilized, or that they are fertilized by the visits of the minute Diptera and Hymenoptera, which are the only insects recorded from these islands.

In Juan Fernandez, on the other hand, there is no such total deficiency of showy flowers. I am informed by Mr. Moseley that a variety of the Magnoliaceous winter-bark abounds and has showy white flowers, and that a Bignoniaceous shrub with abundance of dark blue flowers was also plentiful, while a white-flowered Liliaceous plant formed large patches on the hill-sides. Besides these there were two species of woody Compositæ with conspicuous heads of yellow blossoms, and a species of white-flowered myrtle also abundant; so that, on the whole, flowers formed a rather conspicuous feature in the aspect of the vegetation of Juan Fernandez.

But this fact—which at first sight seems entirely at variance with the view we are upholding of the important relation between the distribution of insects and plants—is well explained by the existence of two species of humming birds in Juan Fernandez, which, in their visits to these large and showy flowers, fertilize them as effectually as bees, moths, or butterflies. Mr. Moseley informs me that "these humming birds are *extraordinarily abundant*, every tree or bush having one or two darting about it." He also observed that "nearly all the specimens killed had the feathers round the base of the bill and front of the head clogged and coloured yellow with pollen." Here, then, we have the clue to the perpetuation of large and showy flowers in Juan Fernandez, while the total absence of humming birds in the Galapagos may explain why no such large-flowered plants have been able to establish themselves in those equatorial islands.

This leads to the observation that many other groups of birds also, no doubt, aid in the fertilization of flowers. I have often observed the beaks and faces of the brush-tongued lories of the Moluccas covered with pollen, and Mr. Moseley noted the same fact in a species of *Artamus* or swallow-shrike shot at Cape York, showing that this genus also frequents flowers and aids in their fertilization. In the Australian region we have the immense group of the Meliphagidæ, which all frequent flowers; and as these range over all the islands of the Pacific, their presence will account for a certain proportion of showy flowers being found there, such as the scarlet *Metrosideros*, one of the few conspicuous flowers in Tahiti. In the Sandwich Islands, too, there are forests of *Metrosideros*, and Mr. Charles Pickering writes me, that they are visited by honey-sucking birds, one of which is captured by sweetened bird-lime, against which it thrusts its extensile tongue. I am also informed that a considerable number of flowers are occasionally fertilized by humming birds in North America, so that there can, I think, be little doubt that birds play a much more important part in this respect than has hitherto been imagined. It is not improbable that in Tropical America, where the humming-bird family is so enormously developed, many flowers will be found to be expressly adapted to fertilization by them, just as so many in our own country are specially adapted to the visits of certain families or genera of insects.

It must also be remembered, as Mr. Moseley has suggested to me, that a flower which had acquired a brilliant colour to attract insects might, on transference to another country, and becoming so modified as to be capable of self-fertilization, retain the coloured petals for an indefinite period. Such is probably the explanation of the *Pelargonium* of Tristan d'Acunha, which forms masses of bright colour near the shore during the flowering season, while most of the other plants of the island have colourless flowers, in accordance with the almost total absence of winged insects. The presence of many large and showy flowers among the indigenous flora of St. Helena must be an example of a similar persistence. Mr. Melliss indeed states it to be "a remarkable peculiarity that the indigenous flowers are, with very slight exceptions, all perfectly colourless"*; but although this may apply to the general aspect of the remains of the indigenous flora, it is evidently not the case as regards the *species*, since the interesting plates of Mr. Melliss's volume show that about one third of the indigenous flowering plants have more or less coloured or conspicuous flowers, while several of them are exceedingly showy and beautiful. Among these are a *Lobelia*, three *Wahlenbergias*, several *Compositæ*, and especially the handsome red flowers of the now almost extinct forest trees, the ebony and redwood (species of *Melhania*, Byttneriaceæ). We have every reason to believe, however, that when St. Helena was covered with luxuriant forests, and especially at that remote period when it was much more extensive than it is now, it must have supported a certain number of indigenous birds and insects, which would have aided in the fertilization of these gaily coloured flowers. The researches of Dr. Hermann Müller have shown us by what minute modifications of structure or of function many flowers are adapted for partial insect- and self-fertilization in various degrees, so that we have no difficulty in understanding how, as the insects diminished and finally disappeared, self-fertilization may have become the rule, while the large and showy corollas remain to tell us plainly of a once different state of things.

Another interesting fact in connexion with this subject is the presence of arborescent forms of Compositæ in so many of the remotest oceanic islands. They occur in the Galapagos, in Juan Fernandez, in St. Helena, in the Sandwich Islands, and in New Zealand; but they are not directly related to each other, representatives of totally different tribes of this extensive order becoming arborescent in each group of islands. The immense range and almost universal distribution of the Compositæ is due to the combination of a great facility of distribution (by their seeds) with a great attractiveness to insects and the capacity of being fertilized by a variety of species of all orders, and especially by flies and small beetles. Thus they would be among the earliest of flowering plants to establish themselves on oceanic islands; but where insects of all kinds were very scarce it would be an advantage to gain increased size and longevity, so that fertilization at an interval of several years might suffice for the continuance of the species. The arborescent form would combine with increased longevity the advantage of increased size in the struggle for existence with ferns and other early colonists; and these advantages have led to its being independently produced in so many distant localities, whose chief feature in common is their remoteness from continents and the extreme poverty of their insect life.

As the sweet odours of flowers are known to act in combination with their colours, as an attraction to insects, it might be anticipated that where colour was deficient scent would be so also. On applying to my friend Dr. Hooker for information as to New-Zealand plants, he informed me that this was certainly the case, and that the New Zealand flora is, speaking generally, as strikingly deficient in sweet odours as in conspicuous colours. Whether this peculiarity occurs in other islands, I have not been able to obtain information; but we may certainly expect it to be so in such a marked instance as that of the Galapagos flora.

Another question which here comes before us is the origin and meaning of the odoriferous glands of leaves. Dr. Hooker informed me that not only are New-Zealand plants deficient in scented flowers, but equally so in scented leaves. This led me to think that perhaps such leaves were in some way an additional attraction to insects—though it is not easy to understand how this could be, except by adding a general attraction to the special attraction of the flowers, or by supporting the larvæ which, as perfect insects, aid in fertilization. Mr. Darwin, however, informs me that he considers that leaf-glands bearing essential oils are a protection against the attacks of insects where these abound, and would thus not be required in countries where insects were very scarce. But it seems opposed to this view that highly aromatic plants are characteristic of deserts all over the world, and in such places insects are not abundant. Mr. Stainton informs me that the aromatic Labiatæ enjoy no immunity from insect attacks. The bitter leaves of the cherrylaurel are often eaten by the larvæ of moths that abound on our fruit-trees; while in the Tropics the leaves of the orange tribe are favourites with a large number of lepidopterous larvæ, and our northern firs and pines, although abounding in a highly aromatic resin, are very subject to the attacks of beetles My friend Dr Richard Spruce—who while travelling in South America allowed nothing connected with plant-life to escape his observation—informs me that trees whose leaves have aromatic and often resinous secretions in immersed glands abound in the plains of tropical America, and that such are in great part, if not wholly, free from the attacks of leaf-eating ants, except where the secretion is only slightly bitter, as in the orange tribe, orange-trees being sometimes entirely denuded of their leaves in a single night Aromatic plants abound in the Andes up to about 13,000 feet, as well as in the plains, but hardly more so than in Central and Southern Europe. They are perhaps more plentiful in the dry mountainous parts of Southern Europe, and as neither here nor in the Andes do leaf-eating ants exist, Dr Spruce infers that, although in the hot American forests where such ants swarm the oil-bearing glands serve as a protection, yet they were not originally acquired for that purpose. Near the limits of perpetual snow on the Andes such plants as occur are not, so far as Dr Spruce has observed, aromatic, and as plants in such situations can hardly depend on insect visits for their fertilization, the fact is comparable with that of the flora of New Zealand, and would seem to imply some relation between the two phenomena, though what it exactly is cannot yet be determined

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* Melliss's St. Helena, p. 226 note.

I trust I have now been able to show you that there are a number of curious problems lying as it were on the outskirts of biological inquiry which well merit attention, and which may lead to valuable results But these problems are, as you see, for the most part connected with questions of locality, and require full and accurate knowledge of the productions of a number of small islands and other limited areas, and the means of comparing them the one with the other To make such comparisons, however, is now quite impossible No museum contains any fair representations of the productions of these localities, and such specimens as do exist, being scattered through the general collection, are almost useless for this special purpose If, then, we are to make any progress in this inquiry, it is absolutely essential that some collectors should begin to arrange their cabinets primarily on a geographical basis, keeping together the productions of every island or group of islands, and of such divisions of each continent as are found to possess any special or characteristic fauna or flora We shall then be sure to detect many unsuspected relations between the animals and plants of certain localities, and we shall become much better acquainted with those complex reactions between the vegetable and animal kingdoms, and between the organic world and the inorganic, which have almost certainly played an important part in determining many of the most conspicuous features of living things

Rise and Progress of Modern Views as to the Antiquity and Origin of Man

I now come to a branch of our subject which I would gladly have avoided touching on, but as the higher powers of this Association have decreed that I should preside over the Anthropological Department, it seems proper that I should devote some portion of my address to matters more immediately connected with the special study to which that Department is devoted

As my own knowledge of and interest in Anthropology is confined to the great outlines rather than to the special details of the science, I propose to give a very brief and general sketch of the modern doctrine as to the Antiquity and Origin of Man, and to suggest certain points of difficulty which have not, I think, yet received sufficient attention.

Many now present remember the time (for it is little more than twenty years ago) when the antiquity of man, as now understood, was universally discredited Not only theologians, but even geologists, then taught us that man belonged altogether to the existing state of things; that the extinct animals of the Tertiary period had finally disappeared, and that the earth's surface had assumed its present condition before the human race first came into existence. So prepossessed were even scientific men with this idea—which yet rested on purely negative evidence, and could not be supported by any arguments of scientific value—that numerous facts which had been presented at intervals for half a century, all tending to prove the existence of man at very remote epochs, were silently ignored, and, more than this, the detailed statements of three distinct and careful observers confirming each other were rejected by a great scientific Society as too improbable for publication, only because they proved (if they were true) the coexistence of man with extinct animals.*

But this state of belief in opposition to facts could not long continue. In 1859 a few of our most eminent geologists examined for themselves into the alleged occurrence of flint implements in the gravels of the north of France, which had been made public fourteen years before, and found them strictly correct. The caverns of Devonshire were about the same time carefully examined by equally eminent observers, and were found fully to bear out the statements of those who had published their results eighteen years before. Flint implements began to be found in all suitable localities in the south of England, when carefully searched for, often in gravels of equal antiquity with those of France. Caverns giving evidence of human occupation at various remote periods were explored in Belgium and the south of France—lake-dwellings were examined in Switzerland—refuse-heaps in Denmark—and thus a whole series of remains have been discovered carrying back the history of mankind from the earliest historic periods to a long distant past. The antiquity of the races thus discovered can only be generally determined by the successively earlier and earlier stages through which we can trace them. As we go back metals soon disappear, and we find only tools and weapons of stone and of bone. The stone weapons get ruder and ruder; pottery, and then the bone implements cease to occur; and in the earliest stage we find only chipped flints of rude design, though still of unmistakably human workmanship. In like manner domestic animals disappear as we go backward, and though the dog seems to have been the earliest, it is doubtful whether the makers of the ruder flint implements of the gravels possessed even this. Still more important as a measure of time are the changes of the earth's surface, of the distribution of animals, and of climate which have occurred during the human period. At a comparatively recent epoch in the record of prehistoric times we find that the Baltic was far salter than it is now and produced abundance of oysters, and that Denmark was covered with pine forests inhabited by Capercailzies, such as now only occur further north in Norway. A little earlier we find that reindeer were common even in the south of France; and still earlier this animal was accompanied by the mammoth and woolly rhinoceros, by the arctic glutton, and by huge bears and lions of extinct species. The presence of such animals implies a change of climate; and both in the caves and gravels we find proofs of a much colder climate than now prevails in Western Europe. Still more remarkable are the changes of the earth's surface which have been effected during man's occupation of it. Many extensive valleys in England and France are believed by the best observers to have been deepened at least a hundred feet; caverns now far out of the reach of any stream must for a long succession of years have had streams flowing through them, at least in times of floods; and this often implies that vast masses of solid rock have since been worn away. In Sardinia land has risen at least 300 feet since men lived there who made pottery and probably used fishing-nets†; while in Kent's Cavern remains of man are found buried beneath two separate beds of stalagmite, each having a distinct texture, and each covering a deposit of cave-earth having well-marked differential characters, while each contains a distinct assemblage of extinct animals.

Such, briefly, are the results of the evidence that has been rapidly accumulating for about fifteen years as to the antiquity of man; and it has been confirmed by so many discoveries of a like nature in all parts of the globe, and especially by the comparison of the tools and weapons of prehistoric man with those of modern savages (so that the use of even the rudest flint-implements has become quite intelligible), that we can hardly wonder at the vast revolution effected in public opinion. Not only is the belief in man's vast and still unknown antiquity universal among men of science, but it is hardly disputed by any well-informed theologian; and the present generation of science-students must, we should think, be somewhat puzzled to understand what there was in the earliest discoveries that should have aroused such general opposition and been met with such universal incredulity.

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* In 1854 (?) a communication from the Torquay Natural History Society confirming previous accounts by Mr. Godwin-Austen, Mr. Vivian, and the Rev. Mr. M'Enery, that worked flints occurred in Kent's Hole with remains of extinct species, was rejected as too improbable for publication.

† Lyell's 'Antiquity of Man,' fourth edition, p. 115.

But the question of the mere "Antiquity of Man" almost sank into insignificance at a very early period of the inquiry, in comparison with the far more momentous and more exciting problem of the development of man from some lower animal form, which the theories of Mr. Darwin and of Mr. Herbert Spencer soon showed to be inseparably bound up with it. This has been, and to some extent still is, the subject of fierce conflict; but the controversy as to the fact of such development is now almost at an end, since one of the most talented representatives of Catholic theology, and an anatomist of high standing—Professor Mivart—fully adopts it as regards physical structure, reserving his opposition for those parts of the theory which would deduce man's whole intellectual and moral nature from the same source and by a similar mode of development.

Never, perhaps, in the whole history of science or philosophy has so great a revolution in thought and opinion been effected as in the twelve years from 1859 to 1871, the respective dates of publication of Mr. Darwin's 'Origin of Species' and 'Descent of Man.' Up to the commencement of this period the belief in the independent creation or origin of the species of animals and plants, and the very recent appearance of man upon the earth, were, practically, universal. Long before the end of it these two beliefs had utterly disappeared, not only in the scientific world, but almost equally so among the literary and educated classes generally. The belief in the independent origin of man held its ground somewhat longer; but the publication of Mr. Darwin's great work gave even that its death-blow, for hardly any one capable of judging of the evidence now doubts the derivative nature of man's bodily structure as a whole, although many believe that his mind, and even some of his physical characteristics, may be due to the action of other forces than have acted in the case of the lower animals.

We need hardly be surprised, under these circumstances, if there has been a tendency among men of science to pass from one extreme to the other, from a profession (so few years ago) of total ignorance as to the mode of origin of all living things, to a claim to almost complete knowledge of the whole progress of the universe, from the first speck of living protoplasm up to the highest development of the human intellect. Yet this is really what we have seen in the last sixteen years. Formerly difficulties were exaggerated, and it was asserted that we had not sufficient knowledge to venture on any generalizations on the subject. Now difficulties are set aside, and it is held that our theories are so well established and so far-reaching, that they explain and comprehend all nature. It is not long ago (as I have already reminded you) since *facts* were contemptuously ignored, because they favoured our now popular views; at the present day it seems to me that facts which oppose them hardly receive due consideration. And as opposition is the best incentive to progress, and it is not well even for the best theories to have it all their own way, I propose to direct your attention to a few such facts, and to the conclusions that seem fairly deducible from them.

It is a curious circumstance that notwithstanding the attention that has been directed to the subject in every part of world, and the numerous excavations connected with railways and mines which have offered such facilities for geological discovery, no advance whatever has been made for a considerable number of years in detecting the time or mode of man's origin. The Palæolithic flint weapons first discovered in the North of France more than thirty years ago are still the oldest undisputed proofs of man's existence; and amid the countless relics of a former world that have been brought to light, no evidence of any one of the links that must have connected man with the lower animals has yet appeared.

It is, indeed, well known that negative evidence in geology is of very slender value, and this is, no doubt, generally the case. The circumstances here are, however, peculiar, for many converging lines of evidence show that, on the theory of development by the same laws which have determined the development of the lower animals, man must be immensely older than any traces of him yet discovered. As this is a point of great interest we must devote a few moments to its consideration.

1. The most important difference between man and such of the lower animals as most nearly approach him is undoubtedly in the bulk and development of his brain, as indicated by the form and capacity of the cranium. We should therefore anticipate that these earliest races, who were contemporary with the extinct animals and used rude stone weapons, would show a marked deficiency in this respect. Yet the oldest known crania (those of the Engis and Cro-Magnon caves) show no marks of degradation. The former does not present so low a type as that of most existing savages, but is (to use the words of Prof. Huxley) "a fair average human skull, which might have belonged to a philosopher, or might have contained the thoughtless brains of a savage." The latter are still more remarkable, being unusually large and well formed. Dr. Pruner-Bey states that they surpass the average of modern European skulls in capacity, while their symmetrical form without any trace of prognathism, compares favourably not only with those of the foremost savage races, but with many civilized nations of modern times.

One or two other crania of much lower type, but of less antiquity than this, have been discovered, but they in no way invalidate the conclusion which so highly developed a form at so early a period implies, viz. that we have as yet made a hardly perceptible step towards the discovery of any earlier stage in the development of man.

2. This conclusion is supported and enforced by the nature of many of the works of art found even in the oldest cave-dwellings. The flints are of the old chipped type, but they are formed into a large variety of tools and weapons—such as scrapers, awls, hammers, saws, lances, &c., implying a variety of purposes for which these were used, and a corresponding degree of mental activity and civilization. Numerous articles of bone have also been found, including well-formed needles, implying that skins were sewn together, and perhaps even textile materials woven into cloth. Still more important are the numerous carvings and drawings representing a variety of animals, including horses, reindeer, and even a mammoth, executed with considerable skill on bone, reindeer-horns, and mammoth-tusks. These, taken together, indicate a state of civilization much higher than that of the lowest of our modern savages, while it is quite compatible with a considerable degree of mental advancement, and leads us to believe that the crania of Engis and Cro-Magnon are not exceptional, but fairly represent the characters of the race. If we further remember that these people lived in Europe under the unfavourable conditions of a sub-Arctic climate, we shall be inclined to agree with Dr. Daniel Wilson, that it is far easier to produce evidences of deterioration than of progress in instituting a comparison between the contemporaries of the mammoth and later prehistoric races of Europe or savage nations of modern times.*

3. Yet another important line of evidence as to the extreme antiquity of the human type has been brought prominently forward by Prof. Mivart†. He shows, by a careful comparison of all parts of the structure of the body, that man is related not to any one, but almost equally to many of the existing apes—to the orang, the chimpanzee, the gorilla, and even to the gibbons—in a variety of ways, and these relations and differences are so numerous and so diverse that, on the theory of evolution, the ancestral form which ultimately developed into man must have diverged from the common stock whence all these various forms and their extinct allies originated. But so far back as the Miocene deposits of Europe we find the remains of apes allied to these various forms, and especially to the gibbons, so that in all probability the special line of variation which led up to man branched off at a still earlier period. And these early forms, being the initiation of a far higher type, and having to develop by natural selection into so specialized and altogether distinct a creature as man, must have risen at a very early period into the position of a

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* Prehistoric Man, 3rd ed. vol. i. p. 117.

† Man and Apes, pp. 171-193.

dominant race, and spread in dense waves of population over all suitable portions of the great continent—for this, on Mr Darwin's hypothesis, is essential to rapid developmental progress through the agency of natural selection.

Under these circumstances we might certainly expect to find some relics of these earlier forms of man along with those of animals, which were presumably less abundant. Negative evidence of this kind is not very weighty, but still it has *some* value. It has been suggested that as apes are mostly tropical, and anthropoid apes are now confined almost exclusively to the vicinity of the equator, we should expect the ancestral forms also to have inhabited these same localities—West Africa and the Malay Islands. But this objection is hardly valid, because existing anthropoid apes are wholly dependent on a perennial supply of easily accessible fruits, which is only found near the equator, while not only had the south of Europe an almost tropical climate in Miocene times, but we must suppose even the earliest ancestors of man to have been terrestrial and omnivorous, since it must have taken ages of slow modification to have produced the perfectly erect form, the short arms, and the wholly non-prehensile foot, which so strongly differentiate man from the arboreal apes.

The conclusion which I think we must arrive at is, that if man has been developed from a common ancestor, with all existing apes, *and by no other agencies than such as have affected their development*, then he must have existed, in something approaching his present form, during the tertiary period—and not merely existed, but predominated in numbers, wherever suitable conditions prevailed. If, then, continued researches in all parts of Europe and Asia fail to bring to light any proofs of his presence, it will be at least a presumption that he came into existence at a much later date, and by a much more rapid process of development. In that case it will be a fair argument that, just as he is in his mental and moral nature, his capacities and aspirations, so infinitely raised above the brutes, so his origin is due, in part, to distinct and higher agencies than such as have affected their development.

There is yet another line of inquiry bearing upon this subject to which I wish to call your attention. It is a somewhat curious fact that, while all modern writers admit the great antiquity of man, most of them maintain the very recent development of his intellect, and will hardly contemplate the possibility of men equal in mental capacity to ourselves having existed in prehistoric times. This question is generally assumed to be settled by such relics as have been preserved of the manufactures of the older races showing a lower and lower state of the arts, by the successive disappearance in early times of iron, bronze, and pottery, and by the ruder forms of the older flint implements. The weakness of this argument has been well shown by Mr Albert Mott in his very original but little-known presidential address to the Literary and Philosophical Society of Liverpool in 1873. He maintains that "our most distant glimpses of the past are still of a world peopled as now with men both civilized and savage," and "that we have often entirely misread the past by supposing that the outward signs of civilization must always be the same, and must be such as are found among ourselves." In support of this view he adduces a variety of striking facts and ingenious arguments, a few of which I will briefly summarize.

On one of the most remote islands of the Pacific—Easter Island—2000 miles from South America, 2000 from the Marquesas, and more than 1000 from the Gambier Islands, are found hundreds of gigantic stone images, now mostly in ruins, often thirty or forty feet high, while some seem to have been much larger, the crowns on their heads cut out of a red stone being sometimes ten feet in diameter, while even the head and neck of one is said to have been twenty feet high *. These once stood erect on extensive stone platforms, yet the island has only an area of about thirty square miles, or considerably less than Jersey. Now as one of the smallest images eight feet high weighs four tons, the largest must weigh over a hundred tons, if not much more, and the existence of such vast works implies a large population, abundance of food, and an established government. Yet how could these coexist in a mere speck of land wholly cut off from the rest of the world? Mr Mott maintains that this necessarily implies the power of regular communication with larger islands or a continent, the arts of navigation, and a civilization much higher than now exists in any part of the Pacific. Very similar remains in other islands scattered widely over the Pacific add weight to this argument.

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* Journ of Roy Geog Soc 1870, pp 177, 178.

The next example is that of the ancient mounds and earthworks of the North-American continent, the bearing of which is even more significant. Over the greater part of the extensive Mississippi valley four well-marked classes of these earthworks occur. Some are camps or works of defence, situated on bluffs, promontories, or isolated hills; others are vast enclosures in the plains and lowlands, often of geometric forms, and having attached to them roadways or avenues often miles in length; a third are mounds corresponding to our tumuli often seventy to ninety feet high, and some of them covering acres of ground; while a fourth group consist of representations of various animals modelled in relief on a gigantic scale, and occurring chiefly in an area somewhat to the north west of the other classes, in the plains of Wisconsin.

The first class—the camps or fortified enclosures—resemble in general features the ancient camps of our own islands, but far surpass them in extent. Fort Hill, in Ohio, is surrounded by a wall and ditch a mile and a half in length, part of the way cut through solid rock. Artificial reservoirs for water were made within it, while at one extremity, on a more elevated point, a keep is constructed with its separate defences and water reservoirs. Another, called Clark's Work, in the Scioto valley, which seems to have been a fortified town, encloses an area of 127 acres, the embankments measuring three miles in length, and containing not less than three million cubic feet of earth. This area encloses numerous sacrificial mounds and symmetrical earthworks, in which many interesting relics and works of art have been found.

The second class—the sacred enclosures—may be compared for extent and arrangement with Avebury or Carnak, but are in some respects even more remarkable. One of these at Newark, Ohio, covers an area of several miles with its connected groups of circles, octagons, squares, ellipses, and avenues on a grand scale, and formed by embankments from twenty to thirty feet in height. Other similar works occur in different parts of Ohio, and by accurate survey it is found not only that the circles are true, though some of them are one third of a mile in diameter, but that other figures are truly square, each side being over 1000 feet long, and, what is still more important, the dimensions of some of these geometrical figures, in different parts of the country and seventy miles apart, are identical. Now this proves the use, by the builders of these works, of some standard measures of length, while the accuracy of the squares, circles, and, in a less degree, of the octagonal figures shows a considerable knowledge of rudimentary geometry and some means of measuring angles. The difficulty of drawing such figures on a large scale is much greater than any one would imagine who has not tried it, and the accuracy of these is far beyond what is necessary to satisfy the eye. We must therefore impute to these people the wish to make these figures as accurate as possible, and this wish is a greater proof of habitual skill and intellectual advancement than even the ability to draw such figures. If, then, we take into account this ability and this love of geometric truth, and further consider the dense population and civil organization implied by the construction of such extensive systematic works, we must allow that these ancient people had reached the earlier stages of a civilization of which no traces existed among the savage tribes who alone occupied the country when first visited by Europeans.

The animal mounds are of comparatively less importance for our present purpose, as they imply a somewhat lower grade of advancement; but the sepulchral and sacrificial mounds exist in vast numbers, and their partial exploration has yielded a quantity of articles and works of art which throw some further light on the peculiarities of this mysterious people. Most of these mounds contain a large concave hearth or basin of burnt clay, of perfectly symmetrical form, on which are found deposited more or less abundant relics, all bearing traces of the action of fire. We are therefore only acquainted with such articles as are practically fireproof, or have accidentally escaped combustion. These consist of bone and copper implements and ornaments, disks, and tubes—pearl, shell, and silver beads, more or less injured by the fire—ornaments cut in mica, ornamental pottery, and numbers of elaborate carvings in stone, mostly forming pipes for smoking. The metallic articles are all formed by hammering, but the execution is very good; plates of mica are found cut into scrolls and circles; the pottery, of which very few remains have been found, is far superior to that of any of the Indian tribes, since Dr. Wilson is of opinion that it must have been formed on a wheel, as it is often of uniform thickness throughout (sometimes not more than one sixth of an inch), polished, and ornamented with scrolls and figures of birds and flowers in delicate relief. But the most instructive objects are the sculptured stone pipes, representing not only various easily recognizable animals, but also human heads, so well executed that they appear to be portraits. Among the animals, not only are such native forms as the panther, bear, otter, wolf, beaver, raccoon, heron, crow, turtle, frog, rattlesnake, and many others well represented, but also the manatee, which perhaps then ascended the Mississippi as it now does the Amazon, and the toucan, which could hardly have been obtained nearer than Mexico. The sculptured heads are especially remarkable, because they present to us the features of an intellectual and civilized people. The nose in some is perfectly straight, and neither prominent nor dilated; the mouth is small, and the lips thin; the chin and upper lip are short, contrasting with the ponderous jaw of the modern Indian, while the cheek-bones present no marked prominence. Other examples have the nose somewhat projecting at the apex in a manner quite unlike the features of any American indigenes; and although there are some which show a much coarser face, it is very difficult to see in any of them that close resemblance to the Indian type which these sculptures have been said to exhibit. The few authentic crania from the mounds present corresponding features, being far more symmetrical and better developed in the frontal region than those of any American tribes, although somewhat resembling them in the occipital outline*; while one was described by its discoverer (Mr. W. Marshall Anderson) as a "beautiful skull worthy of a Greek."

The antiquity of this remarkable race may perhaps not be very great as compared with the prehistoric man of Europe, although the opinions of some writers on the subject seem affected by that "parsimony of time" on which the late Sir Charles Lyell so often dilated. The mounds are all overgrown with dense forest, and one of the large trees was estimated to be eight hundred years old, while other observers consider the forest growth to indicate an age of at least 1000 years. But it is well known that it requires several generations of trees to pass away before the growth on a deserted clearing comes to correspond with that of the surrounding virgin forest, while this forest, once established, may go on growing for an unknown number of thousands of years. The 800 or 1000 years estimate from the growth of existing vegetation is a minimum which has no bearing whatever on the actual age of these mounds; and we might almost as well attempt to determine the time of the glacial epoch from the age of the pines or oaks which now grow on the moraines.

The important thing for us, however, is that when North America was first settled by Europeans, the Indian tribes inhabiting it had no knowledge or tradition of any preceding race of higher civilization than themselves. Yet we find that such a race existed; that they must have been populous and have lived under some established government; while there are signs that they practised agriculture largely, as, indeed, they must have done to have supported a population capable of executing such gigantic works in such vast profusion; for it is stated that the mounds and earthworks of various kinds in the state of Ohio alone amount to between eleven and twelve thousand. In their habits, customs, religion, and arts they differed strikingly from all the Indian tribes; while their love of art and of geometric forms, and their capacity for executing the latter upon so gigantic a scale, render it probable that they were a really civilized people, although the form their civilization took may have been very different from that of later people subject to very different influences, and the inheritors of a longer series of ancestral civilizations. We have here, at all events, a striking example of the transition, over an extensive country, from comparative civilization to comparative barbarism, the former left to tradition and having hardly any trace of influence on the latter.

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* Wilson's 'Prehistoric Man,' 3rd ed. vol. ii. pp. 123–130.

As Mr Mott well remarks:—Nothing can be more striking than the fact that Easter Island and North America both gave the same testimony as to the origin of the savage life found in them, although in all circumstances and surroundings the two cases are so different. If no stone monuments had been constructed in Easter Island, or mounds, containing a few relics saved from fire, in the United States, we might never have suspected the existence of these ancient peoples. He argues, therefore, that it is very easy for the records of an ancient nation's life entirely to perish or to be hidden from observation. Even the arts of Nineveh and Babylon were unknown only a generation ago, and we have only just discovered the facts about the mound-builders of North America.

But other parts of the American continent exhibit parallel phenomena. Recent investigations show that in Mexico, Central America, and Peru the existing race of Indians has been preceded by a distinct and more civilized race. This is proved by the sculptures of the ruined cities of Central America, by the more ancient terra-cottas and paintings of Mexico, and by the oldest portrait-pottery of Peru. All alike show markedly non-Indian features, while they often closely resemble modern European types. Ancient crania, too, have been found in all these countries, presenting very different characters from those of any of the modern indigenous races of America.*

There is one other striking example of a higher being succeeded by a lower degree of knowledge, which is in danger of being forgotten because it has been made the foundation of theories which seem wild and fantastic, and are probably in great part erroneous. I allude to the Great Pyramid of Egypt, whose form, dimensions, structure, and uses have recently been the subject of elaborate works by Prof. Piazzi Smyth. Now the admitted facts about this pyramid are so interesting and so apposite to the subject we are considering, that I beg to recall them to your attention. Most of you are aware that this pyramid has been carefully explored and measured by successive Egyptologists, and that the dimensions have lately become capable of more accurate determination, owing to the discovery of some of the original casing-stones and the clearing away of the earth from the corners of the foundation showing the sockets in which the corner-stones fitted. Prof. Smyth devoted many months of work with the best instruments in order to fix the dimensions and angles of all accessible parts of the structure; and he has carefully determined these by a comparison of his own and all previous measures, the best of which agree pretty closely with each other. The results arrived at are:—

1. That the pyramid is truly square, the sides being equal and the angles right angles.
2. That the four sockets on which the four first stones of the corners rested are truly on the same level.
3. That the direction of the sides are accurately to the four cardinal points.
4. That the vertical height of the pyramid bears the same proportion to its circumference at the base, as the radius of a circle does to its circumference.

Now all these measures, angles, and levels are accurate, not as an ordinary surveyor or builder could make them, but to such a degree as requires the very best modern instruments and all the refinements of geodetical science to discover any error at all. In addition to this we have the wonderful perfection of the workmanship in the interior of the pyramid, the passages and chambers being lined with huge blocks of stones fitted with the utmost accuracy, while every part of the building exhibits the highest structural science.

In all these respects this largest pyramid surpasses every other in Egypt. Yet it is universally admitted to be the oldest, and also the oldest historical building in the world.

Now these admitted facts about the Great Pyramid are surely remarkable, and worthy of the deepest consideration. They are facts which, in the pregnant words of the late Sir John Herschel, "according to received theories ought not to happen," and which, he tells us, should therefore be kept ever present to our minds, since "they belong to the class of facts which serve as the clue to new discoveries." According to modern theories, the higher civilization is ever a growth and an outcome from a preceding lower state, and it is inferred that this progress is visible to us throughout all history and in all the material records of human intellect. But here we have a building which marks the very dawn of history, which is the oldest authentic monument of man's genius and skill, and which, instead of being far inferior, is very much superior to all which followed it. Great men are the products of their age and country, and the designer and constructors of this wonderful monument could never have arisen among an unintellectual and half barbarous people. So perfect a work implies many preceding less perfect works which have disappeared. It marks the culminating point of an ancient civilization, of the early stages of which we have no record whatever.

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* Wilson's 'Prehistoric Man,' 3rd ed. vol. ii. pp. 125, 144.

The three cases to which I have now adverted (and there are many others) seem to require for their satisfactory interpretation a somewhat different view of human progress from that which is now generally accepted. Taken in connexion with the great intellectual power of the ancient Greeks—which Mr. Galton believes to have been far above that of the average of any modern nation—and the elevation, at once intellectual and moral, displayed in the writings of Confucius, Zoroaster, and in the Vedas, they point to the conclusion that, while in material progress there has been a tolerably steady advance, man's intellectual and moral development reached almost its highest level in a very remote past. The lower, the more animal, but often the more energetic types have, however, always been far the more numerous; hence such established societies as have here and there arisen under the guidance of higher minds have always been liable to be swept away by the incursions of barbarians. Thus in almost every part of the globe there may have been a long succession of partial civilizations each in turn succeeded by a period of barbarism; and this view seems supported by the occurrence of degraded types of skull along with such "as might have belonged to a philosopher," at a time when the mammoth and the reindeer inhabited southern France.

Nor need we fear that there is not time enough for the rise and decay of so many successive civilizations as this view would imply; for the opinion is now gaining ground among geologists that palæolithic man was really preglacial, and that the great gap (marked alike by a change of physical conditions and of animal life) which in Europe always separates him from his neolithic successor, was caused by the coming on and passing away of the great ice age.

If the views now advanced are correct, many, perhaps most, of our existing savages are the successors of higher races, and their arts, often showing a wonderful similarity in distant continents, may have been derived from a common source among more civilized peoples.

I must now conclude this very imperfect sketch of a few of the offshoots from the great tree of Biological study. It will, perhaps, be thought by some that my remarks have tended to the depreciation of our science, by hinting at imperfections in our knowledge and errors in our theories where more enthusiastic students see nothing but established truths. But I trust that I may have conveyed to many of my hearers a different impression. I have endeavoured to show that, even in what are usually considered the more trivial and superficial characters presented by natural objects, a whole field of new inquiry is opened up to us by the study of distribution and local conditions. And as regards man, I have endeavoured to fix your attention on a class of facts which indicate that the course of his development has been far less direct and simple than has hitherto been supposed; and that, instead of resembling a single tide with its advancing and receding ripples, it must rather be compared to the progress from neap to spring tides, both the rise and the depression being comparatively greater as the waters of true civilization slowly advance towards the highest level they can reach.

And if we are thus led to believe that our present knowledge of nature is somewhat less complete than we have been accustomed to consider it, this is only what we might expect; for however great may have been the intellectual triumphs of the nineteenth century, we can hardly think so highly of its achievements as to imagine that, in somewhat less than twenty years, we have passed from complete ignorance to almost perfect knowledge on two such vast and complex subjects as the origin of species and the antiquity of man.

BOTANY AND ZOOLOGY

Address to the Department of Botany and Zoology. By ALFRED NEWTON, *M.A., F.R.S., F.L.S., V.P.Z.S., &c., Professor of Zoology and Comparative Anatomy in the University of Cambridge, Vice-President.*

Any one in the position of chairman of this Department must feel that his difficulty lies in choosing rather than in seeking a subject whereon to address an audience like that which is before me. This difficulty arises from the astounding abundance of interesting topics which are presented by the studies of Botany and Zoology—or of the latter alone, I may say, since it would ill become me to attempt the treatment of any which belong to the sister science. But it is of course incumbent upon me to touch upon the chief events of the past year which affect this Department, and it seems possible that in so doing we may find some considerations naturally proceeding from them to be worthy of your notice during the short time that I shall presume to occupy your attention, and also to present enough general interest to justify my enlarging upon the themes which they inspire.

These chief events appear to me to be two in number. It is my first and pleasing duty to congratulate the naturalists here assembled on the successful termination of that expedition in which we have all taken so great an interest, as during its progress tidings of it have reached us from one distant land after another, and especially (as your mouth-piece) heartily to welcome home all now present who were on board the good ship 'Challenger' in her circumnavigation of the globe. I would that your spokesman on this occasion had been one who was better able to appreciate their labours and enter into details as to the value of their discoveries and researches. Unfortunately I am under the great disadvantage of being so imperfectly acquainted with the mysteries of the ocean, that it is only possible for me to speak in the most general terms of what has been done. I feel sure, however, that, so far as the great secrets of the sea can yet be interpreted and revealed by men, they will be by those who have happily returned to us, Sir Charles Wyville Thomson and his colleagues. There is one of their company we know they have not brought back, and it is fitting for us to lower the tone of our exultation while we remember the name of Von Willemoes-Suhm. With this single sad exception there is, however, nothing, so far as I know, to occasion regret, and the various memoirs that have been already published by members of the Expedition give a foretaste of what we may expect when the whole of its results are made known. I am informed that the rich collections made during the voyage are at present lodged in the University of Edinburgh, and are in process of revision and rough arrangement under the superintendence of the Director of the Scientific Staff of the late Expedition. They include the products of dredging or trawling and surface-collecting at about 350 stations, and at depths varying from 100 to 4500 fathoms, and consist of a prodigious number of specimens belonging to most of the groups of marine *Invertebrata*, especially of Sponges and Echinoderms, which preponderate at the greatest depths. It is, I believe, intended to obtain the assistance of special experts in working out the different groups; and I am sure this meeting will hear with pleasure that the *Hydrozoa* are to be intrusted to Professor Allman, and the *Polyzoa* to Mr Busk. It is understood that Her Majesty's Treasury will charge itself with the cost of publishing the treatises of these and the other eminent naturalists to be employed, and thus it is hoped that a series of volumes will be produced worthy of the magnitude of the subject, and fit for the first rank among the works of zoologists in this or any other country. I need scarcely add that the wishes of all here will be for the due carrying-out of this grand scheme;

and, remembering how often similar ambitious undertakings by our scientific men in combination with our Government have been baulked by untoward circumstances, we cannot but express the sincere hope that former failures will serve as useful warnings to ensure future success. I regret extremely my inability to say more on this subject.

I trust you will not think me to underrate the importance of the safe and prosperous return of the 'Challenger' from her voyage, when, though naming it first, I ascribe to it the second place in the events of the past year as regards the progress of zoological investigation. Other scientific expeditions have before now left these shores and the shores of other countries and have more or less fully attained their purpose, while other expeditions will doubtless in due time be organized and carried out with, we trust, like happy results. The voyage of the 'Challenger,' though a highly important and, in many respects, a novel one, is notwithstanding only a unit in a long series which began a century ago and has been continued at intervals to our own day. Nay more, since the sailing of the 'Challenger' we have witnessed the departure of another and larger expedition for the accomplishment of a still more arduous undertaking. But what I have now to speak of is a matter that will, if I am not mistaken, in after ages characterize the present year as an epoch in the history of our science inferior only in importance to that which marked some eighteen or nineteen years ago the promulgation of a reasonable Theory of Evolution by Mr. Darwin and Mr. Wallace. And while it is to the latter of these two naturalists that we owe the boon that has recently been conferred on us, it is unquestionably from the former labours of both—united yet distinct—that the boon acquires its greatest value. Without those far higher, far wider views which the Theory of Evolution enables us to take, the serried array of facts that bristle throughout the two volumes of the 'Geographical Distribution of Animals'* which Mr. Wallace has just published would have been but a comparatively meaningless aggregation of statements—the evidence no doubt of labour almost unsurpassed, the accumulation of much that is curious and of much that is suggestive, but, taken all in all, as serving to an unintelligible or insignificant end, if to any end whatever that was not misleading.

As the case is, the result is very different. But I would ask you now, Without the aid afforded by the Doctrine of Descent, would it have been possible to draw, as Mr. Wallace has so skilfully drawn, those legitimate conclusions from a consideration of the animal life of Java (vol. i. pp. 352-353), or to arrive at those marvellous results with respect to the past history of Borneo (vol. i. pp. 358-359), or even to indulge in those daring speculations with regard to the origin of the Celebesian fauna (vol. i. pp. 436-438)? I cite these instances because they are taken from that part of the world on which the author's labours have before shed so much light, and with which his name is imperishably associated; but there is hardly any one of his summaries that does not place before us material for reflection as astounding.

While, however, assigning to the Theory of Evolution the chief glory in giving a real and lasting value to the interpretation of the facts of Animal Distribution, I must not omit acknowledging the share which Physical Geography has contributed to that end, especially by its marine surveys, which furnish the zoologist with data as to the depths of seas and oceans, and thereby enable him to judge as to the former extent of land. It is therefore to be expected that voyages like that of the 'Challenger,' when their results have been fully worked out, will still further add to our knowledge in this respect. Again too, Geology (but this follows almost as a matter of course) has in its own line played an equal part. I would that Botany could be mentioned in this connexion, but here it seems as if the eldest of the biological sciences were not, as she usually is, in advance of the rest, and Mr. Wallace's suggestion (vol. ii. p. 162), that Zoology furnishes a key wherewith many of the difficulties besetting the study of the Distribution of Plants may be unlocked, will doubtless meet with due attention from botanists.

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* 'The Geographical Distribution of Animals, with a study of the relations of living and extinct Faunas as elucidating the past changes of the Earth's Surface.' By Alfred Russel Wallace, Author of 'The Malay Archipelago,' &c. 8vo, two vols. London: 1876.

Of the care and labour which the author of this work has bestowed upon it, no one here, I venture to think, has a better right to speak than myself, because it is not very long ago that I attempted a dissertation on the Geographical Distribution of a single Class of animals*. Though it was the Class with which I am most familiar, and though in my attempt I had the invaluable assistance of Mr. Wallace's manuscript at my side, which cleared my way through many obstacles, still I found the task one of enormous difficulty, and one which I at times almost repented that I had undertaken, yet Mr. Wallace has treated not of Birds only, as I did, but of Mammals, Amphibians, Reptiles, and Freshwater Fishes—to say nothing of the most telling Families of two orders of Insects, with the Mollusks so far as they were available for his purpose. There is nothing that in turning over the pages of these volumes so much strikes one as the energy they evince on the part of their author. Those who have been most accustomed to the literature of zoology must admit that there is scarcely any book with which 'The Geographical Distribution of Animals' may not, in respect of hard and honest work, be advantageously compared. It deserves to bear good fruit, and I am greatly mistaken if it will not do so. From an educational point of view, it can hardly fail to be of the greatest service. Attractive as is the subject to those that know it and see its bearings, the learner has hitherto been repelled from its consideration by the want of any work of general compass which would guide his studies, while even few of those treatises which have a particular scope were of much use to him. Mr. Wallace has now placed one in his hands, and the result we need not try to anticipate. One thing, however, is clear—the Distribution of Animals can no longer be neglected as a secondary or unimportant part of Zoology. It only remains for me to add, while thus attempting to set forth the general merits of this learned work, that I by no means pin my faith to all the author's details or to all his conclusions. Most of the latter may indeed be justified by the present imperfect state of our knowledge, but it does not follow that they will eventually meet with common acceptance. I must particularly call your attention to the admirably cautious words in which he takes leave of his readers—words that prove him to be thoroughly imbued with the right spirit of a true worker in a progressive branch of study. Mr. Wallace says:—

"The preceding remarks are all I now venture to offer, on the distinguishing features of the various groups of land-animals as regards their distribution and migrations. They are at best but indications of the various lines of research opened up to us by the study of animals from the geographical point of view, and by looking upon their range in space and time as an important portion of the earth's history. Till every well-marked district,—every archipelago, and every important island, has all its known species of the more important groups of animals catalogued on a uniform plan, and with a uniform nomenclature, a thoroughly satisfactory account of the Geographical Distribution of Animals will not be possible."

And then he goes on to point out that more than this is wanted:—

"Many of the most curious relations between animal forms and their habitats, are entirely unnoticed, owing to the productions of the same locality never being associated in our museums and collections. A few such relations have been brought to light by modern scientific travellers, but many more remain to be discovered, and there is probably no fresher and more productive field still unexplored in Natural History."

These coincident variations, he concludes by saying, "have never been systema-

the hidden laws (supplementary to Natural Selection), which seem to be required in order to account for many of the external characteristics of animals" (vol. ii. pp. 552, 553).

And now to follow out the idea with which I began. Having touched on the two chief zoological events of the year, let us see if they do not suggest something that will not be beneath your consideration for the remainder of this address. I have spoken of the certainty of the expedition from which we now welcome our friends being succeeded by others of similar character We shall hardly be indulging any vain imagination if we ask ourselves what we may look forward to as regards their reports, and to one point we may perhaps usefully apply ourselves

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* "Geographical Distribution of Birds," Encyclopædia Britannica, Ed. 9, vol. iii. pp. 736–764.

What if a future 'Challenger' shall report of some island, now known to possess a rich and varied animal population, that its present fauna has disappeared? that its only Mammals were feral Pigs, Goats, Rats, and Rabbits—with an infusion of Ferrets, introduced by a zealous "acclimatizer" to check the superabundance of the rodents last named, but contenting themselves with the colonists' chickens? that Sparrows and Starlings, brought from Europe, were its only Land-birds, that the former had propagated to such an extent that the cultivation of cereals had ceased to pay—the prohibition of bird-keeping boys by the local school-board contributing to the same effect—and that the latter (the Starlings) having put an end to the indigenous insectivorous birds by consuming their food, had turned their attention to the settlers' orchards, so that a crop of fruit was only to be looked for about once in five years—when the great periodical cyclones had reduced the number of the depredators? that the Goats had destroyed one half of the original flora and the Rabbits the rest? that the Pigs devastated the potatoe-gardens and yam-grounds? This is no fanciful picture I pretend not to the gift of prophecy, that is a faculty alien to the scientific mind, but if we may reason from the known to the unknown, from what has been and from what is to what will be, I cannot entertain a doubt that these things are coming to pass, for I am sure there are places where what is very like them has already happened

You may ask why this is so? why do these lands so speedily succumb to the strangers from beyond sea? One part of the answer is ready to hand with those who have learned one of the first principles of biology which our great master, Mr Darwin, has laid down for us The weaker, the more generalized forms of life must always make way for the stronger and more specialized The other part of the answer is supplied by Mr Wallace, for no one can have studied his volumes to much purpose without perceiving that the inhabitants of oceanic islands and of the southern hemisphere—the great Australian Region especially, and South America not much less, are the direct and comparatively speaking little-changed descendants of an older, a more generalized and a weaker fauna than are the present inhabitants of this quarter of the globe, which have been, so to speak, elaborated by Nature and turned out as the latest and most perfect samples of her handiwork.

Set face to face with unlooked-for invaders, and forced into a contest with them from which there is no retreat, it is not in the least surprising that the natives should succumb. They have hitherto only had to struggle for existence with creatures of a like organization, and the issue of the conflict which has been going on for ages is that, adapted to the conditions under which they find themselves, they maintain their footing on grounds of equality among one another, and so for centuries they may have "kept the noiseless tenor of their way" Suddenly man interferes and lets loose upon them an entirely new race of animals, which act and react in a thousand different fashions on their circumstances. It is not necessary that the new comers should be predacious, they may be so far void of offence as to abstain from assaulting the aboriginal population, but they occupy the same haunts and consume the same food The fruits, the herbage, and other supplies that sufficed to support the ancient fauna now have to furnish forage for the invaders as well. Their effects on the flora there is no need for me to trace, since Dr. Hooker expressly made them one of the themes of that discourse to which many of us listened with rapt attention a few years since at this Association But the consequences of the invasion to the native fauna have never been so fully made known. The new comers are creatures whose organization has been prepared by and for combat throughout generations innumerable. Their ancestors have been elevated in the scale of being by the discipline of strife. Their descendants inherit the developed qualities that enabled those ancestors to win a hard-fought existence when the animals around them were no higher in grade than those among which the descendants are now thrown. Can we doubt that the victory inclines to the heirs of the ancient conquerors? The struggle is like one between an army of veterans and a population unused to warfare. It is that of Spaniards with matchlocks and coats of mail against Aztecs with feather cloaks and bows and arrows. *Mala salus victis.* A few years, and the majority of native species are exterminated. But this is not the worst. The species which perish most quickly are just those that naturalists would most wish to preserve, for they are those peculiar and endemic forms that in structure and constitution represent the ancient state of things upon the earth, and supply us with some of the most instructive evidence as to the Order of Nature.

With the progress of civilization it is plain that there will soon be hardly a land but will bear the standard of a European nation or of a community of European descent, and, as things are going on, be overrun by their imports. If this were inevitable it would be useless to complain. But is it inevitable? Is it not obvious that most of this extermination is being carried on unwittingly? and may not some of it be avoided by proper precautions? If so, should not men of science make a stand, and interest the ignorant or careless in the importance of the subject? I cannot divest myself of the belief that the course of the next century will see the extirpation, not only of most of the peculiar faunas I had in view a few minutes ago, but of a great multitude of other species of animals throughout all parts of the world. The regret with which I regard such extirpation is not merely a matter of sentiment. Here sentiment and science are for once on the same side. A heavy blow will be inflicted on Zoology by the disappearance of some of these marvellous and peculiar forms. There is no one species of animal whose structure and habits have been so completely investigated that absence of the means of further examination would not be a distinct deprivation to Science; and as what Science has done is only an earnest of what she will do, we cannot say that the time shall ever come when the want of those means will not be severely felt. It is then for scientific men, and for naturalists especially, to consider whether they are not bound, in the interest of their successors, to interpose more than they have hitherto given any sign of doing.

But outside this audience there are many who care little for consequences like these. Such persons may, however, be impressed by thinking that the indiscriminate destruction of animals which, in one way or another, is now going on, must sooner or later lead to the extirpation of many of those which minister to our wants, whether of comfort or luxury. The fur-bearing creatures will speedily, if they do not already, require some protection to be generally accorded to them; and that such protection can be effectually given is evident if we take the trouble of inquiring as to the steps taken by the Russian local authorities in Alaska, and now, I believe, continued by those of the United States, for limiting the slaughter of the Sea-Otter and the Fur-Seals of the adjacent islands to particular seasons. No one can suppose that, even with the assistance we get from Siberia, our supply of ivory will continue what it now is when the interior of Africa is pacified and settled, as we can hardly doubt that it one day will be; and, unless we can find some substitute for that useful substance before that day comes, it would be only prudent to do something to check the wasteful destruction of Elephants. Many people may think that the continent of Africa is too vast and its animal life too luxuriant for the efforts of man materially to affect it. If we inquire, however, we shall find that this is not the case, and that there is an enormous tract of country, extending far beyond our colonies and the territories of the neighbouring Republics, from which most of the larger Mammals have already disappeared. There is good reason to believe that at least one species has become extinct within the last five-and-twenty years or thereabouts; and though I do not mean to say that this species, the true Zebra, had any economic value, yet its fate is an indication of what will befall its fellows; while to the Zoologist its extirpation is a matter of moment, being probably the first case of the total extinction of a large terrestrial mammal since the remote days when the *Megaceros hibernicus* disappeared.

Time would fail me if I attempted to go into particulars with regard to the marine *Mammalia*. It is notorious that various members of the Orders *Sirenia*, *Cetacea*, and *Pinnipedia* have recently dwindled in numbers or altogether vanished from the earth. The Manatee and Dugong have been recklessly killed off from hundreds of localities where but a century or so since they abounded, and with them the stores of valuable oil that they furnished have been lost. That very remarkable Sirenian the huge *Rhytina gigas* has become utterly extinct. The greed of whalers is believed to have had the same effect on a Cetacean (the *Balæna biscayensis*) which was once the cause of a flourishing industry on the coasts of France and Spain. The same greed has almost exterminated the Right Whale of the northern seas, and is fast accomplishing the same end in the case of Seals all over the world. You are probably aware that an Act of Parliament passed in the session of 1875 was intended to put some check upon those bloody massacres that annually take place on the floating ice of the North Atlantic, to which these creatures resort at the time of bringing forth their young, when

Sires in their children in one carnage lie.

But, whether through official indifference, or what, I know not, the treaties with foreign nations authorized by that Act were not completed, and last spring, at the solicitation of certain Aberdeen or Peterhead shipowners, the Board of Trade allowed "one year more of wholesale slaughter." Whatever other nations might like to do, our hands at least should have been unstained! It is admitted that in certain manufactures—that of jute for instance—animal oil is absolutely necessary. It is easy to see that before long there will be very little animal oil forthcoming.

There is another Class of animals with whose well-being the interests of man are largely connected. It cannot be denied that our Fisheries are year by year subjected to an ever increasing strain, through the rapidly increasing population of these islands, and are giving unmistakable signs of being unable to bear it. But it must be admitted that the consideration of their case is fraught with unusual difficulties. Commissions, either Royal or Parliamentary, have been appointed one after another to inquire into the facts and to seek a remedy, if one is to be found, for the falling off. It is with great diffidence that I venture to pass any criticism on the recommendations made by those Commissions, and especially on such as were contained in the Report of a Commission the constitution of which was such as to inspire the greatest respect, since men so eminent as Prof. Huxley and Mr. Holdsworth were named in it. That Commission reported in effect that there was nothing to be done with our Sea-Fisheries but to leave things alone. I do not profess to quote the words of the Report (which, indeed, I have not seen for a long time), but in substance, I believe, it amounted to this:—That the natural enemies to which Fishes were exposed were so multitudinous, so crafty, and so rapacious that their destruction by man was very slight in comparison, and that his interference might be safely neglected in considering its consequences. Now it has always seemed to me that the Commissioners on this occasion suffered themselves to be deceived. Well aware of how little is known as to the indirect effects of man's acts in regard to the lower animals, and in their fear lest any unforseen bad results should follow from measures intended to be remedial, they recommended none at all. But I fail to discern that land or sea makes any essential difference in the laws of life. The balance of Nature must be preserved as steadily in a dense as in a rare fluid—in water as in air—or all will not go well. Whatever be the weight in either scale, equipoise is as easily destroyed by an ounce as by a ton. The marine Fishes that are of such commercial importance (Cod, Herrings, and the like) have naturally, no doubt, enemies innumerable—Dogfish, Cormorants, Porpoises, and what not; but we know that, owing to their fertility and habits, the Cod and Herrings have continued till lately to contend successfully with these drawbacks and to maintain their numbers. It matters not if only one egg of the 10,000, or whatever be the number in the roe of a Herring, produces a fish that arrives at maturity and escapes its natural enemies, so long as that one fish is sufficient to supply the place of its parent. Now this, according to the arrangement of Nature, has hitherto been the case. But if, instead of that fish living to propagate its kind, it is cut off before its time by an enemy against whom Nature has made no provision, her balance is at once destroyed; and the oftener the operation is repeated the sooner will the numbers of the species dwindle, and the dwindling will go on in a rapidly accelerated ratio. Therefore it seems that, so far from leaving our Sea-Fisheries unrestricted, it is highly necessary to impose some limitation upon them; and, so far from dreading interference, our interference is at present so fatal that further interference of another kind is required as a counterbalance, while that counterbalance Science only can apply.

As much may be said for those other industries, in common speech also called "fisheries"—the taking of Oysters, Crabs, and Lobsters, all of which have lately been diminishing in a still more alarming degree. Here Parliament has wisely resolved to interpose, though whether the manner of interposition is wise seems to be a matter on which, as few naturalists have been consulted, we had better reserve our opinion.

Thus, without troubling you with many technical details, I have striven to lay before you a sketch of man's treatment of some of his fellow-creatures, and of the effects which have sprung, or certainly will spring, from it. There is probably hardly an island on which he has set foot, the fauna and flora of which has not been in some degree influenced by his even temporary presence; there is assuredly not a continent, though a continent takes longer to subdue; and his control does not stop at the shore, for, if what I have been advancing is true, the inhabitants of the deep come also more or less under his dominion. I invite you to contemplate whether it is always, or even generally, that of a beneficent ruler. But it will doubtless be urged that this kind of thing has gone on for ages—ever since life first existed on the earth. I may be told, in the words of the great poet of the country in which we now find ourselves,—

"Look abroad through Nature's range,
Nature's mighty law is change
* * * * * * *
Why then ask of silly man,
To oppose great Nature's plan?"

I would answer from the same source that

" — man, to whom alone is giv'n
A ray direct from pitying Heav'n,"

should by means of that ray not oppose Nature, but rather second her preservative measures. That ray is the ray of Science. We can only govern Nature by obeying her, only by obeying her can we assist her. To obey her laws we must know them; what can we know of them but what Science teaches us?

It may be said that I have taken too gloomy a view of this matter of the extirpation of animals by man. I wish I could think so. But I believe that if we go to work in the right way there is yet time to save many an otherwise expiring species. In this country there is happily a strong disposition, which grows stronger day by day, to preserve our wild animals. It is very desirable that this feeling should not be limited to the British Islands. If it is, as I maintain, a right feeling—a feeling sanctioned alike by humanity, by Science, and by our own material interests—it cannot be too widely disseminated. But its propagation must not be left to humanitarians and sentimentalists, whose efforts are sure to be brought to nothing through ignorance and excess of zeal, nor to economists, whose endeavours would unquestionably fall short of what is required. The officiousness of the one class and the slackness of the other must equally be tempered by the naturalist. He can be trusted not to interfere with the use, but with the abuse, of the animal world. Only to do this he must place himself in the forefront of the movement; for he can submit to no other leader. He alone has, or should have, that knowledge which gives the power of coping successfully with the difficult questions that will arise; and the advantage it gives him he must not abstain from exercising. If, without offence, I might here paraphrase some venerable words, I would say that, according to the greatness of this power, we must preserve those that are otherwise appointed to die.

Anatomy and Physiology.

The Future of Physiological Research.—Address to the Department of Anatomy and Physiology. By John Grey M'Kendrick, *M.D., Fellow of the Royal College of Physicians, and of the Royal Society, of Edinburgh.*

Bearing in mind the fact that one of the objects of the British Association is to interest the public in the advancement of scientific truth, it has been the practice of the Presidents of the various Sections to make some remarks of a general character, or to give a *résumé* of the recent progress of science in their particular department. I shall follow so far the example of my predecessors. I shall not attempt to enumerate, far less to describe, the contributions made to anatomical and physiological science during the past year, because that would entail a long and wearisome report regarding investigations with which most of us are already acquainted by the perusal of those excellent summaries that appear from time to time in our scientific and medical periodicals. With the view of limiting the scope of this address, I propose to offer a few observations bearing generally upon some of the scientific and social relations of anatomy and physiology, with the view of interesting the public in what we have been doing, and what we hope yet to do.

These sciences present different views of the same great system of truth. Each can be conceived as existing independently, while at the same time the one science is the complement of the other. Anatomy is the science of organic form, while physiology is that of organic function. The anatomist investigates structure, its form, general arrangements, and laws, and he may include in his survey the purposes or functions which the structure fulfils. Recently an opinion has been prevalent, and has cropped up in various quarters, that anatomy is but a preparatory science for physiology. This opinion has probably arisen in consequence of the rapid growth of physiological science during the last twenty or thirty years. But there can be no doubt that anatomy has a *rôle* of her own by no means inferior to that of physiology. She has to educe formal laws which determine the structure of organized bodies and their parts, and thus she establishes the basis for scientific classification and arrangement. Anatomy is the beginning, of course, of all medical education, and the groundwork on which the practical arts of medicine and surgery are reared, but in a broader sense, the science has to do with the structure of every animal, from the simplest to the most complex, and from the facts obtained in the investigation of the structure of any animal, we are able to recognize the relationships it has with other animals, or, in other words, its position in the Zoological scale.

Methods of Anatomy.

The methods of anatomical science are dissection, description, and comparison. These methods have been followed by anatomists from the birth of the science; but in recent times they have been largely supplemented by the use of the microscope, and by the employment of various modes of preparing tissues for microscopical inquiry. Now-a-days the anatomist not only describes naked-eye appearances displayed by the art of dissection, but he scrutinizes every tissue and organ with the aid of the microscope. Hence it is, the historian of the progress of anatomical knowledge in this century will have to relate, as one of its chief features, the development of microscopical anatomy or histology. In no department of scientific work is greater activity manifested at present than in this. Scarcely a month passes without adding materially to our stores of knowledge, so as to make it almost impossible for a man to keep abreast of modern histology, and at the same time devote due attention to other departments of anatomy and physiology. In Germany and France men devote their energies to histology as to the business of their lives, and occupy chairs in many universities distinct from those of anatomy and physiology. In this country, from social and other considerations, such a division of labour is not generally made, but the time will assuredly come when it must be done.

HISTOLOGY.

It may be supposed from these remarks that I regard histology as lying entirely within the province of anatomy. By no means. Histology is neutral territory between both. It is that department of knowledge where the two sciences overlap. The physiologist must investigate minute structure, in which the beginnings of physiological processes take place, because without knowledge of it all his ideas as to functions of organs or tissues would be superficial and unsatisfactory. When a physiologist examines a tissue, or a section of an organ, however, the morphological aspect is not what is prominently before his mind, but its mode of function. To him the form, size, position, and relations of the cell are not the special subjects of interest, but its probable mode of action in the economy. He therefore wishes it could be seen working, or at all events in conditions as nearly normal as possible. This desire has already led to the invention of various new methods of research, such as those of the hot stage, or plans for the observations of changes in cells or fibres in parts accessible to the microscope, methods which have already been fruitful of good results. I have a firm belief that this line of work has by no means been followed to the end, and that along it the physiologist will still be conducted to rich harvests in the fields of histological research.

METHODS OF PHYSIOLOGY.

The kindred science of physiology has for its object the elucidation of function, and it has, in addition to the methods of anatomy (namely, dissection, description, and comparison), those of pathological observation and experimentation. It is confessedly the science most difficult of all to prosecute. The subjects of investigation are intricate in structure, and are formed of complex chemical materials, which are in constant interaction with the surrounding world. Each animal is a machine, the intricacies of which are infinitely more involved than those of any human manufacture. To stop this machine, in the attempt to discover the action of one of its parts, is a proceeding, in many instances, which interferes with the very part the action of which we wish to find out. As we descend in the scale of animal life, and the machine becomes less complex, this difficulty is not so obtrusive, inasmuch as in many animals of simple organization there is not the same dependence of organ upon organ, and of tissue upon tissue, as we find in the more complex. But in most experimental researches in other sciences the conditions are also manifold, and the acumen of the philosopher in all is tested in distinguishing the essential from the non-essential conditions.

In the further prosecution of physiology as a physical science, which it really is, experimental inquiry, with the aid of precise instruments, and the facts derived from the observation of the course and effects of disease, seem to me to be the two lines of evidence which will in future weigh with us in coming to just conclusions. No doubt it is quite true that much of the minute anatomy of the human body, and more so of the minute anatomy of the bodies of the lower animals, is still unknown, and that there are probably many details, visible only to the microscope, not yet discovered, which may influence our opinions as to the exact functions of parts. This is especially true of the structure of the nerve-centres. We have at present only very general conceptions of the arrangements of the cells and fibres in these parts, and it is highly probable that future discoveries in this difficult field of investigation may change our views, not only of nervous action in general, but of the functions of particular centres. Accordingly there can be little doubt that as the naked-eye dissection has revealed structural arrangements which have hitherto guided the physiologist to correct notions of function, so in the future a similar service will be done to physiology by the histologist. Still physiology will have to depend less on aid of this nature, and more on the facts obtained by the methods of pathological observation and experiment These methods are essentially of the same order They vary the circumstances of the phenomenon we wish to investigate, and by the application of well known logical rules, we succeed in eliminating the cause of a phenomenon from its indifferent accompaniments Diseased conditions, as has been well said, are experiments ready at hand, and every physician and surgeon of scientific spirit is from day to day engaged in investigating these conditions not only with the view of curing his patient but with the hope of throwing light on complex physiological processes But direct experiment has the advantage over the observation of pathological effects that it enables us to vary the conditions of the phenomenon as we desire Thus the functions of the nerves were ascertained by the experiment of dividing each in turn, and watching the effect When a function is arrested immediately on the division of a nerve, it is held that that function requires the nerve in order to its performance

THE VIVISECTION QUESTION

I make these remarks regarding the value of the experimental method in physiology because we cannot forget the attempt which has recently been made to restrict us in the use of this important aid in prosecuting our science I shall not enter again upon the controversy which has raged in this country regarding experiments upon animals because by the passing of the Bill a practical solution of the question has been arrived at in the mean time, and it now becomes us, as good citizens, to do all in our power to carry out the provisions of the act and to give it a fair trial *I may be permitted to say, however, that I* always recognized the right of the public to agitate on this question if they considered that cruelty was being perpetrated I hope the day will never come when tales of suffering inflicted either on man or beast will be heard by us with calm indifference The complaint I have against a section of the public is, that they believed apparently all they were told and condemned us without waiting for explanation or defence At the same time it was not wise to meet this agitation *with contempt and scorn for the ignorance of those who carried it on*, and it seems to me that the appointment of a Royal Commission to investigate the facts of the case was the best thing that could have been done by the Government That Commission was composed of three eminent statesmen—Lord Cardwell, Lord Winmarleigh, and Mr Forster of a great lawyer, skilled in the art of obtaining and weighing evidence Sir John Karslake, of one of the leading biologists in this country, Professor Huxley, of a surgeon who knew the relation of physiology to the practical art of treating disease, Mr Erichsen *and of a leading journalist* and most able thinker, Mr Hutton, the editor of the 'Spectator' Thus composed of men likely by character and previous training to ascertain the truth, and to suggest wise procedures it held numerous meetings, examined witnesses partial and impartial, collected a body of evidence of a most interesting and diverse character, and gave in a report which, while it recommended legislation, is generally in favour of physiologists No one can read the evidence in the blue book, and the report *founded thereon, without coming to the conclusion that the case of those who* raised the outcry against physiologists in this country completely broke down On considering this report the Government brought in a Bill, certain of the provisions of which seemed not only oppressive to physiologists, but were calculated, if carried into law, to impede the progress of science The members of the medical profession who knew the value of the experimental method in physiological research, and who were painfully conscious of the many imperfections of the art due to want *of knowledge, were now aroused, and, by a use of the machinery of the 'British* Medical Association' they aided the few physiologists of the country in making representations to the Government, which were favourably received, and which led to important modifications in the bill That bill has now passed into law, and I appeal to our opponents to desist from further agitation The case has been tried and the verdict has been given For my own part I was all along opposed to legislation as being quite unnecessary in the circumstances, but I had, at the same time, *that confidence in the common-sense* and good feeling *of our legislators, as to* expect a bill favourable to physiologists when the facts were put before them. Some of our opponents, led away by their feelings, have put in print many erroneous statements. Hosts of pamphlets have been circulated, many of them well meant, but utterly wrong both in form and matter. For a season these pamphlets produced effects, and many people of good intentions were led astray. But a reaction began, and when the leading members of the medical profession came forward boldly and stated their opinions, it was soon completed.

The only preventive for such casual excitements is the diffusion of knowledge. I have no belief whatever in the theory that most people are fools on questions of this kind. The great majority of our people of both sexes are perfectly capable of reasoning and of forming sound opinions. What they require is knowledge, evidence, and representations strong enough to overcome the bias of prejudice. I therefore warn our opponents that if the agitation be continued, we will appeal to the bar of public opinion. We will instruct the public through the press, on the platform, and by the pamphlet, and I have no fear of what the issue will be. The fact that the members of the medical profession who, by knowledge and habits of thought, are best competent to judge in this matter, acted as they did, indicates at once the result.

IMPORTANCE OF TEACHING BIOLOGY.

This leads me to say a word as to the diffusion of biological knowledge among the people. I regard this as one of the healthiest signs of our day. A general knowledge of the structure and functions of the human body, of its necessities, of those agencies which act prejudicially upon it, and of those conditions which favour long life, the relief of pain, the prevention of sickness, and the transmission of healthy offspring, cannot fail in being of high practical importance. Furthermore, the acquisition of knowledge of the general laws of life as seen in the various living things about us, in addition to being an intellectual training of great value, will probably engender a feeling of kindness for every living thing, and thus even animals will share in the benefit. At one time knowledge of this kind was almost wholly reserved for the medical profession; but now it is taught in every village school. The instruction of ladies in a knowledge of the general structure and functions of the human body has recently been successfully carried on in various parts of the country, more especially in Edinburgh and Cambridge; and I can state, from my own experience of this matter, that there is no difficulty whatever in so treating the subject as to make it interesting and instructive without giving it too much of a professional character. The effect of education of this kind will be that, within one or two generations, many social questions will be viewed more from the physiological standpoint than at present; doctors will be able to give an intelligible explanation to their patients of their condition, when it is deemed judicious to do so—a feat not easy of performance at present; the management of the sick will be better attended to on more rational principles; quackery will waste away by degrees, because it will have no ignorance and credulity on which to feed; and legislation will be prompted in many instances not by emotional agitations, but by enlightened views of the physical nature of men.

I cannot help mentioning the name of Professor Huxley in connexion with the introduction of this great subject among our educational appliances, both as to what should be taught, and how to teach it; and it may not be considered presumptuous in me to predict that this alone will entitle him to a place in the thoughts of posterity.

PRACTICAL ASPECTS OF ANATOMY AND PHYSIOLOGY.

There is an impression in the minds of many regarding our scientific work which I would like to remove; and here I direct my remarks, not to purely scientific men, but to the public. Many still think that anatomy and physiology have no practical side, and consequently they do not take that interest in their prosecution which they otherwise would do. The results of the triumphs of physics, chemistry, and engineering are so patent to all as to excite universal interest, so that you will often find a man of average intelligence readily engrossed in any new discovery of physics or of chemistry, while he is indifferent to new facts in the domain of biological science. This state of mind, of course, is due to a want of appreciation of the practical aspect of our work, and I hold that till the man be better informed, he is quite entitled to take this view of the matter. But I wish to point out that, although our sciences occupy their own place as abstract systems of truth, bearing no apparent relation to the wants either of humanity or of the lower animals, still they have also a practical aspect of the highest importance. My belief is that every advance in science, by adding to the sum of human knowledge, and thus enabling man to have a correct idea of his true position in the universe, and of his relations to it, will ultimately promote both his own material well-being and that of the other living things about him. I do not see how it can be otherwise, and the history of the past supports this view. Knowledge promotes civilization; and the progress of civilization, on the whole, lessens suffering and increases the physical sources of happiness both to man and beast. The thought must therefore be urged, that every research, however far removed it may appear to be at first from having any relation to the welfare of living things, occupies its place in leading to this grand consummation—life, liberty, and happiness to all. From many illustrations which occur to the mind, I shall take only one. M. Pasteur proved that in the atmosphere there exist germs or particles of matter, call them what you will, which excited fermentation and putrefaction in certain fluids. Of this, I think there cannot be any reasonable doubt. Whether fermentation be always the result of the presence of germs is another question, upon which I shall not enter, nor shall I engage on a discussion of the question of so-called spontaneous generation, which, though highly probable, has never, in my opinion, been proved. These investigations of Pasteur, relating to which a great controversy has taken place, referred to animal and vegetable organisms of the very humblest type, organisms so small that to prove their very existence in the air, indirect and complicated methods of procedure had to be adopted. But Mr. Lister, who once occupied the Chair of Surgery in this University, and who now adorns the Chair of Clinical Surgery in Edinburgh, was attracted, whilst he was in Glasgow, by the doctrines of the eminent French chemist; he repeated experiments to satisfy himself of their truth, and he came to the conclusion that these particles in the air are the sources of disturbance in wounds, leading to suppuration, putrefaction, and many grave constitutional symptoms. To remove the influence of these germs, he devised the antiseptic system of treating wounds, a system first put into operation in this city, and which is attended with great success in the hands of those who practice it carefully. Slowly but surely this system—the greatest advance in surgery since the days of John Hunter—is winning its way in this country, on the continent, and in America. The surgical mind is eminently conservative and not easily convinced; but it gives way after a struggle, and the benefit both of the preliminary caution and of the subsequent vigorous adoption is to humanity. What does the practice of this system of treating wounds mean? It means, speaking generally, the banishment of pyæmia and surgical fever from hospitals, the possibility of performing many serious operations with comparative safety to the patient, the relief of pain in the dressing of wounds, and the saving of human lives. I need scarcely add that Professor Lister did much in his earlier years to give him a high place among British physiologists, but, in addition, he has showed the successful application of purely scientific knowledge to the advancement of the art of surgery; and in suggesting a method by which life may be saved and suffering mitigated, he has earned the gratitude of humanity.

Importance of Investigations on the Physiological Action of Active Substances.

There is another field of physiological research which promises to confer great practical benefit on the human race. I refer to the investigation of the physiological action of active substances, which may lead us not only to the discovery of important therapeutic agents, but to a knowledge of the relation which exists between the chemical constitution of a substance and its physiological effects Already a considerable amount of work of this kind has been accomplished The physiological action of the various anæsthetics (such as chloroform, chloral, alcohol, &c), of narcotics (such as morphia, narceine, narcotine, codeine, and many others), and of alkaloids (such as strychnine, brucine, nicotine, atropine, hyoscyamine, physostigmine, muscarine, veratrine, aconitine, digitaline, santonine, ergotine, and quinine) has been carefully studied The celebrated research of Professor Crum Brown and Dr Thomas R Fraser, upon the physiological action of the methyl-, amyl-, and ethyl-substitution compounds of certain alkaloids, in which they showed that a change in chemical composition was attended by a change in physiological action, opened up a new field of discovery. The investigations of Dr B W Richardson on the action of homologous series of alcohols and ethers, and the observations made by Professor Dewar and myself on the action of the chinoline and pyridine series of bases, and their substitution compounds, all tended to illustrate the same general truth Nor must I forget to mention an interesting series of investigations made by Professor Gamgee, of Manchester, and his pupils, communicated to our Section and at the present meeting, on the action of various compounds of the rare metal vanadium, on the action of chromium salts, and on the differences between the physiological actions of ortho-, meta-, and pyro-phosphoric acids. Here, again, we had a further illustration of the important facts that the physiological action of any active substance is affected (1) by the number of atoms in the molecule and its complexity of structure, and (2) by the degree of stability of the molecule That is to say, the more complex the molecule, the more intense and prolonged will its action probably be, and, on the other hand, if the molecule of a substance tend readily to break down or split up while circulating in the blood, it will act more intensely than if it held firmly together for a considerable time. These generalizations are merely tentative We have not yet sufficient data to entitle us to term them general laws

Now no one can glance over any work on organic chemistry without seeing on every page the names of substances regarding the physiological action of which we know nothing I would not have these investigated in a promiscuous manner, with the vague hope of coming upon something new Here, as elsewhere in science, we must be guided so far by the light cast upon the unknown by former discoveries, and by those general laws which have been formulated by previous investigators Nor is the mere discovery of new poisons any thing but a "sorry task," unless the research lead us to an agent likely to be of therapeutic value, or to the enunciation of an important general principle But former experience warrants us in hoping, nay in expecting, that new useful agents will yet be discovered. I need not refer to the practical applications of chloroform and ether, as these are too well known to need any eulogy from me, but I may be allowed to direct attention to chloral, first discovered by Liebig in 1832, and known for many years merely as the ultimate product of chlorine upon alcohol It was only a few years ago that Liebreich, of Berlin, pointed out its important physiological action, and it is now recognized as a therapeutic agent of the highest value. Its use, no doubt, has often been sadly abused, and people have often trifled with a powerful physiological agent even to the loss of their lives, but when we think of the hours of pain which many a weary sufferer has escaped by its use, we cannot but regard it as a boon to humanity

Here the physiologist must go hand in hand with the chemist The chemist in his laboratory prepares the substances, and builds up new compounds by those wonderful synthetic processes which are now the glory of his science, it is then the duty of the physiologist to investigate the actions of these By united work, who can foretell what may be accomplished? For example, may we not hope to see the day when such a substance as quinine, or a substance having similar therapeutic properties, may be produced artificially, or, may we not obtain an anæsthetic as potent and even less dangerous than those at present employed?

Nor have we yet investigated the physiological action of the active principles of thousands of plants, many of which may prove to be of great value. Let us remember the well-known words of Shakespeare, as Romeo—the love-stricken

Romeo—repairs to Friar Lawrence's cell, "when grey-eyed morn smiles on the frowning night The old friar thus soliloquizes —

' I must up-fill this osier cage of ours
With baleful weeds and precious juiced flowers

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Many for many virtues excellent
None but for some and yet all different
O mickle is the powerful grace that lies
In herbs plants stones and their true qualities

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Within the infant rind of this weak flower
Poison hath residence and medicine power
For this being smelt with that part cheers each part
Being tasted slays all senses with the heart
Romeo and Juliet Act II Scene 3

I cannot help noticing here in passing, that Shakespeare appears to have conceived the notion of the physiological antagonisms of drugs, which is generally regarded as quite modern, although the practice of using antidotes has been followed from the earliest times Thus in the interview between the Queen and Cornelius, the physician, in Cymbeline, she says —

Having thus far proceeded
(Unless thou think'st me devilish) is't not meet
That I did amplify my judgment in
Other conclusions? I will try the forces
Of these thy compounds on such creatures as
We count not worth the hanging (but none human)
To try the vigour of them and apply
Allayments to their act and by them gather
Their several virtues and effects —*Cymbeline* Act I Scene 6

RELATION OF PHYSIOLOGY TO MEDICINE

I may now be permitted to say a few words regarding the present position or attitude of physiological science I am in the habit of thinking of physiology, not only as a physical science in itself, but as having a direct relation to two other sciences—medicine and psychology Carrying out this idea, were a sculptor to form a group, he might represent physiology, on the one hand, dispensing gifts and affording assistance to medicine, and, on the other, pointing upwards to psychology as the greater sister of the three Abandoning metaphor, there can be no doubt physiology is most intimately connected with those sciences First of all, with regard to medicine (and by this term of course I mean the whole art of detecting and curing disease), there are many problems which physiology alone can solve The origin of disease, the steps of the changes by which organs and tissues become so altered as to produce what is called a diseased state, the effects of one diseased organ upon others which are healthy, the actions of remedial substances, both in the healthy and in the diseased condition, are all physiological processes, many of which cannot, in the present condition of society, be thoroughly investigated by a practitioner, who is often too busy a man to engage in this kind of work Such labour must be handed over, to a large extent, to a special class of men They must investigate, experiment, and work up the subject in the laboratory—either the physiological laboratory of the university or school of medicine, or of the hospital or infirmary—as the business of their lives, and from time to time announce the results These results must be checked by past experience, or by a knowledge of cases apposite to the point, by the men who come into daily contact with patients, and their verdict, so far as any practical benefit is concerned, must usually be regarded as final

IMPORTANCE OF SYSTEMATIC INVESTIGATION OF DISEASES

In the present state of science, we have not reached that subdivision of labour, nor need it be ever absolutely complete Many of the best contributions to physiological and pathological science, during the past twenty years, have been from men busy in practice. Such busy men will, no doubt, always be found in the ranks of the medical profession, and they will contribute so far to the advancement of medicine; but in the future, much scientific work, as a basis of the practical treatment of disease, must be done by men specially devoted to the laboratory, the pathological theatre, and the clinical ward. The origin and progress of those diseased processes which cause cancer, tubercle, rheumatism, and gout, with all their attendant evils, the discovery of the poisons which produce fever in its manifold forms, the modes of counteracting these poisons so as to arrest the progress of fever at an early stage, and the investigation of those diseases which destroy thousands of our domestic animals, are all subjects which must be investigated more systematically and on a larger scale than has yet been done. Such stupendous work can scarcely be left to individual effort. To carry it on requires men, time, and money; and these can only be supplied by the aid of governments, of municipalities, or by private munificence. Already excellent work has been done by Professor Burdon Sanderson and his coadjutors, by Dr. Klein, and by Dr. Thudichum, for the Medical Officer of the Privy Council, and by Professor Rutherford, Dr. Braidwood, and others, at the instance of the British Medical Association; but still the amount of aid given is small alongside of what is lavished, for example, in warlike experiments. Compared with what is needed for the manufacture, testing, and equipment of an 80-ton gun, designed to destroy human life and property (no doubt on the theory that it is for the ultimate welfare of the State to do so), a small sum would be necessary; but authorities do not yet see the vast importance of inquiries of this kind, and consequently consider two or three thousand pounds per annum sufficient. We accept gratefully what help is given; but we look for more. I hope to see the day when Government will equip and thoroughly furnish a body of men for the investigation on a large scale of the genesis of such diseases as tubercle or of typhus fever, both of which kill in Great Britain alone thousands of people annually, just as they have sent out a 'Challenger' expedition to explore the depths of the sea, or have at present a number of brave men engaged in the attempt to discover the North Pole. To strike at the root of one of those great maladies that afflict the human race, such as cancer, tubercle, or fever, would confer an inestimable blessing on humanity, and honour on the Government that proposed and carried out the undertaking.

Relation of Physiology to Psychology.

As I have said, physiology is intimately connected with psychology, or of the science of the mind; and as this department of physiological work has lately been my chief study, I may be allowed to refer to it a little more in detail.

Psychology may be divided into two parts:—first, all those phenomena which we may include under the term mind properly so called, such as feeling, volition, and intellectual processes; and second, the phenomena which are associated with, and which indicate the alliance between, mind and matter. Every mental act may be regarded in the present state of knowledge as having a double aspect—on the one side it is known to our consciousness, and on the other side it is the result of a number of physical processes occurring in the brain.

The Methods of Psychology.

In the investigation of mental phenomena, two modes of inquiry have been hitherto followed. First, that of introspection and reflection, in which the investigator looks within himself for the facts of his experience; and second, that of the examination of physiological processes which coincide with sensorial or mental changes. It is evident that the first of these methods, usually called the subjective, is open to the objection that by it a mind attempts to observe its own operations, and that the proceeding is somewhat analogous to asking a machine to investigate its own mechanism. This objection, urged in other words by Comte, Maudsley, and others, may be answered by replying that the subjective method does not attempt to explain the physiological phenomena concomitant with mental states, but the laws which regulate these mental states themselves. Suppose a complicated machine possessed consciousness, I can readily understand that by the exercise of this consciousness it might be unable to discover the relation and mechanism of its own parts, because in attempting to do so the machinary would be so interfered with as to prevent normal action, but it might still be able to study the products of its operations. I do not, therefore, decry this old method of psychological research as it is so much the fashion to do in these days. Apart altogether from the philosophical speculations and systems of philosophy founded upon them, I think many data accumulated by such men as Locke, Berkeley, David Hume, Thomas Reid, Dugald Stewart, Thomas Brown, Sir William Hamilton, and James Mill have as good a right to be considered correct as some of the quasi metaphysical conceptions of modern physical science. Subjective inquiry carried on by such men cannot be given up as a mode of psychological research. It may not carry us much further than it has done, but it has rendered good service already, and may possibly do more.

But, on the other hand, the objective method appears to me to be the one which, in future, will be principally cultivated, and it is for this reason that, as a physiologist, I wish especially to refer to it.

It is the business of physiology to supply psychology with information regarding physical processes occurring in the nervous system, and it is one of the special features of the physiology of the present day to direct attention to the physical side of mental phenomena. No doubt Aristotle, Hobbes and Hartley incorporated into their psychological theories much that was purely physiological, but in their days the physiology of the nervous system was in a crude state, and, consequently, did not lead to great results. In comparatively recent times, a new inductive and experimental department of science has arisen, the nature of which is indicated by the term physiological psychology and which is being diligently cultivated by numerous workers, both at home and abroad. In our own country the writings and researches of Herbert Spencer, Alexander Bain, Dr Laycock, George Henry Lewes, Dr Maudsley, Dr Carpenter, Alfred Barratt, and James Sully, and on the continent those of Fechner, Helmholtz, Wundt, Hermann Lotze, Taine, Donders, Plateau, and Delbœuf, have excited much interest, and have led to the formation of a new school of thought.

I think it right to mention here specially the name of Professor Laycock, who has done more in my opinion in this field of inquiry than any other member of the medical profession of this country in our time. His teaching has largely contributed to our present humane methods of treating the insane. He has attracted year by year some of the best students of the University of Edinburgh to this important department of medical practice, and his earlier writings incontestibly show that many years ago, and prior to most of the writings of those great men whose names I have just enumerated, he not only recognized the value of physiological research with regard to mental phenomena, but made important contributions himself.

Physiology has thus encroached on psychology, and is attempting to supply from the objective side an explanation of at least the simpler mental phenomena. As a proof of awakened interest in this department, one of the features of the past year has been the appearance of 'Mind,' a quarterly journal of psychology, edited by my able friend Professor Croom Robertson of University College. In the prospectus of this journal it is stated that "psychology, while drawing its fundamental data from subjective consciousness, will be understood in the widest sense, as covering all related lines of objective inquiry. Due prominence will be given to the physiological investigation of nerve-structure." This quotation indicates the view which the editor takes of the relation of the two sciences, and already valuable papers have appeared on subjects connected with physiological psychology, from the pens of Sully, Lewes, Wundt, and others.

Now a certain class of thinkers are alarmed by work of this kind. They are afraid of the tendency "to represent the mental fact as a physical fact," and they are inclined to shut their eyes to the physical facts connected, undoubtedly, with psychological processes, and to be contented with the study of subjective phenomena. But as most admit that there are two aspects in which mental phenomena may be viewed, why should not both be looked at carefully? If it be also admitted that it is impossible to connect any physical process (supposing we know it) occurring in brain-cells with an act of consciousness, what is the use of taking a one-sided view of the phenomena in question? Why not study both sides of the problem, and give up the attempt at reconciliation, which is entirely beyond the pale of our faculties? This mystery of mind and matter has puzzled thoughtful men from the earliest times. Some have attempted a reconciliation. They have reasoned in a circle, so that most people, after perusing their works, are no nearer an ultimate solution than they were at the beginning. We always come back to this view of the case, namely, that every fact of mind has two aspects, a physiological and a psychological. That is one way of looking at the problem, and it is the one which in the present state of knowledge personally I prefer. But there is another. Thus, as has been well argued by Mr George Henry Lewes in his recent work, 'Problems of Life and Mind,' two very different descriptions may be given of one and the same mental activity. The one may be expressed in the language of psychology, which is the language we commonly use to describe our feelings; the other may be stated in the language of physiology, a language intelligible only to those acquainted with the present state of physiological research. He says, "All that we have to guard against is the tendency to mistake difference of aspect for difference of process, and to suppose that changes in feeling can exist independently of changes in the organism, or that any change in the organism can be effected otherwise than by some previous change." This way of stating the question may be more satisfactory to some minds. At all events it is a fair attempt to solve the puzzle of our present state of existence, in which we are constantly brought face to face with the antithesis of object and subject.

Abandoning these speculations, which are fruitless in practical effects, let me now endeavour very briefly to indicate the lines of inquiry in the domain of physiology along which progress has been and may be made in the attempt to solve psychological phenomena; and I wish it to be understood that I do not take these in any logical order, but merely adduce them by way of illustration. It will also be my aim not so much to describe what has been done in the past, as to indicate what remains to be done in the future.

RESEARCH IN PHYSIOLOGICAL PSYCHOLOGY.

First of all, then, it is quite evident that all researches on the general physiology of the great nerve centres are of paramount importance. Such researches as those of Hitzig, Fritsch, and Ferrier on the excitability of the cerebral hemispheres, supplying new ideas regarding the mechanism of the brain as a compound organ; of Wundt on central innervation and consciousness, in which he discusses in a manner never before attempted the phenomena of reflex excitation; of William Stirling on the summation of excitations in reflex mechanisms; of various French physiologists on the mode of action of ganglia in Insecta; and of many others, are all recent important contributions to this department of science. Here, however, we have to confess that we have little accurate information regarding the minute structure of the parts involved, and consequently no anatomical basis on which to found our views. We have a general idea of strands of nerve-fibres and groups of nerve-cells of various forms, but we have no precise knowledge of the relative quantity of these, or of the relation of one group of nerve-cells to another group. We are unacquainted with any peculiarity in structure, for example, by which even an accomplished histologist could identify three microscopical sections as respectively portions of the brain of a man, of a monkey, and of a sheep. All this has still to be work out. Every little area of brain-matter has to be surveyed and carefully described. Supposing this were done in the case of the human brain, and of the brains of the higher animals, the same must be attempted with the brains of animals lower in the scale. I can then conceive a grand collection of facts which may throw light on the intricate working of different kinds of brains, and, perhaps, afford a rational explanation of certain simple psychological characters

SUGGESTED INVESTIGATION.

What I mean may perhaps be better understood by a research which I would suggest by way of experiment. No one who has kept an aviary of small birds—say a collection of our native and foreign finches—can have failed to observe marked differences of character and habits among different members of the same genus, and even among different members of the same species. One manifests cunning, another combativeness, a third kindness to smaller brethren, a fourth bullies all about him, a fifth may usually be quiet and peaceable, but occasionally gives way to uncontrollable rage, and so on. The question arises, then, Have these psychological peculiarities any organic basis, any explanation in the structure of the brain? or, Are we to rest satisfied by asserting that these peculiarities are due to the action of some kind of psychical principle regarding which we know nothing? I have little doubt most will agree that these psychical characteristics of birds depend on peculiarities of brain-structure the result of hereditary transmission through many generations. If so, here we have an opportunity of examining the microscopical structure of small brains, relatively simple, and easy of manipulation, with the view of ascertaining whether or not there are any structural differences which may account for these differences in psychical character. This is a line of inquiry likely, in my opinion, to establish an organic basis for a comparative psychology.

RECENT RESEARCHES ON THE CHEMISTRY OF THE BRAIN.

But in studying the physiology of the brain as an organ of mind (and the same holds good with regard to the other great nerve-centres) we must not forget that, in addition to mere structure, two other factors have to be taken into notice. These are, first, the chemical constitution of the brain itself, and, second, the amount of chemical interchange that goes on between it and the blood. There are so many exceptions to the general rule, that size of brain and number of convolutions are proportional to the degree of mental power, as to render it highly probable that to account for these exceptions we must assume differences of minute structure, differences of chemical constitution, and differences of chemical interchange between blood and brain. That is to say, we may have two brains equal in size and in number of convolutions belonging to two individuals very unequal in mental capacity. This may be accounted for either by supposing that the minute structure of a convolution of the one may be more intricate than that of the other, or the one brain may be richer in certain complicated chemical compounds, the splitting up of which into simpler bodies is necessary in processes of thought; or, finally, the activity of chemical interchanges between the blood and the brain may be much more rapid in the one than in the other. All this, however, must remain a matter of conjecture until we know more of the chemistry of the brain than we at present do. I have therefore hailed with satisfaction the appearance of an elaborate paper by Dr. Thudicum, entitled, "Researches on the Chemical Constitution of the Brain," in a recent volume of 'Reports of the Medical Officer of the Privy Council and Local Government Board.' It is impossible to give here a detailed account of this laborious inquiry, in which Dr. Thudicum and his assistant, Mr. C. T. Kingzett, have analyzed the brains of oxen, requiring no fewer than a thousand of these in the undertaking. The result, generally speaking, has been the discovery of seventeen compounds, for the first time detected as ingredients in brain-matter, and in an appendix, Dr. Thudicum gives a list of no fewer than eighty-two substances which have been detected, by himself and other chemists, in the brain. Even admitting, what is highly probable, that many of these are products of the decomposition of a few more complex substances, still we obtain from a mere inspection of this list some idea of the intricate chemical nature of this part of our bodies.

Various striking thoughts are put forth by Dr. Thudicum at the end of his paper, a few of which I may be allowed to refer to with the view of showing how chemical considerations may assist us in our conceptions of the working of the nervous system. He says, "During these proceedings the first striking fact which meets the inquirer is, that nerve-matter contains abundance of water. This, in conjunction with the peculiar manner in which the water is contained, engenders a mobility of ultimate particles within certain limits of movement. It also gives penetrability by liquid diffusion, while excluding porosity and its capillary effects, by which means a ready nutrition by diffusion in one direction, and ready cleansing from the effete crystallizable products of life in another are assured. Consequently the brain as a whole is essentially made up of colloid matter, and may be compared to a colloid septum, on the one side of which is arterial blood and cerebro-spinal fluid of the ventricles, on the other side, however, is cerebro-spinal fluid of the arachnoideal space and venous blood. It follows from this that the large amount of water present in the brain is not there, so to say, mechanically only, like water in a sponge, and capable of being pressed out mechanically, but is chemically combined as colloid hydration water, or, better, water of colloidation."

Dr. Thudicum divides a large amount of the matter occurring in the brain into three groups, viz. phosphorized bodies, consisting of carbon, oxygen, hydrogen, nitrogen, and rich in phosphorus; nitrogenized bodies, containing only carbon, oxygen, hydrogen, nitrogen, and no phosphorus; and, third, oxygenized bodies, formed of carbon, hydrogen, and oxygen alone. The phosphorized bodies he divides into three subgroups, termed kephalines, myelines, and lecithines. Each of these has certain definite chemical characteristics, which he summarizes as follows:—"The kephalines possess the tendency to be oxydized, oxydizability; the myelines are not easily changed by any agent or influence, and possess therefore stability; the lecithines easily fall to pieces, they are afflicted with lability."

He then points out the remarkable tendency of the phosphorized bodies to combine with other substances, showing a diversity of affinities "not possessed by any other class of chemical compounds in nature at present known." He shows that these affinities are influenced by the amount of water present, and by the mass of the substance or reagent presented to the brain-matter, so that the interchange "of affinities may produce a perfectly incalculable number of states of the phosphorized, and consequently of brain-matter. This power of answering to any qualitative and quantitative chemical influence by reciprocal quality or quantity we may term the state of *labile equilibrium*; it foreshadows on the chemical outside the remarkable properties which nerve-matter exhibits in regard of its vital functions."

All of these remarks by Dr Thudicum point to a field of research which will not be explored for many a year to come. But there can be little doubt that when the chemical statics of the brain have been accurately ascertained, we will be in a position to study the chemical interchanges between the blood and the nervous tissue. Should the skill of our physiological chemists succeed in unravelling these, then we will be in a position to understand at least two different sets of phenomena. These are—(1) the chemical changes which undoubtedly take place during the occurrence of mental phenomena; and (2) the exact nature of the action of such substances as alcohol, narcotics, and the various alkaloids which are known to act on the nervous system. I need scarcely add that accurate knowledge regarding the physiological action of these substances would probably be of great service in the treatment of disease.

Researches on Sensory Impressions.

In the second place, researches into the physiology of the senses afford another series of data for the physiologist. These researches may be said to be of three kinds—(1) inquiries into the anatomical and physiological mechanism of the sense-organ itself, such as, in the case of vision, the general structure of the eye as an optical instrument, and its movements by the action of muscles, so as to secure the conditions of monocular or binocular vision; (2) inquiries into the nature of the specific action of the external stimulus upon the terminal organ of sense, and the transmission of the effect to the brain—as, for example, the action of light on the retina, and transmission along the optic nerve; and (3) experiments in which various stimuli are permitted to act under certain conditions on the terminal apparatus, and the result is observed and recorded by the consciousness of the experimentalist himself, as in researches on colour, duration of impressions on the retina, positive and negative, after images, &c. By these three modes of inquiry a large number of facts relating chiefly to the senses of hearing and vision have been collected; and most of these facts, inasmuch as they assist him in understanding the conditions of sensory impressions and sensational effects, are of importance to the psychologist.

MEASUREMENT OF TIME IN SENSORY IMPRESSIONS

The next step of importance made by physiology into the domains of psychology is the measurement of time or duration in sensational effects* This has been carefully measured by objective methods Speaking generally, the time occupied from the commencement of the action of the stimulus to the termination of a sensation may be divided into four portions, each of which has a certain psychological interest —First, an interval of time is occupied by the primary physical change produced by the stimulus. During this interval, called the period of latent stimulation, no effect is observed Thus, when a motor nerve distributed to a muscle is stimulated by a short electrical shock, about 1-60th of a second passes before the muscle contracts Second, when the change in the nerve or terminal organ has begun, a second interval of time is occupied in the transmission of the impression to the nerve-centre, which is succeeded by a third interval, during which changes occur in the nerve-centre, and the result of which is a sensation The time occupied in transmission, or the rate of conductivity in nerve, is tolerably well known, being at the rate of about 200 feet per second in the nerves of men, but the time occupied in the production of the sensation in the centre has not yet been clearly ascertained, owing to the difficulty of supposing such a sensory nerve-centre to be, previous to the stimulus, in a state of absolute inaction Lastly, it has been found that when a nervous action of any kind has been initiated by a stimulus, it goes on for some time after the stimulus has ceased to act This prolongation of the sensation may be well studied in the case of impressions on the eye, where the time of the duration of the impression has been measured by Helmholtz, Plateau, and others These distinguished observers also found that the length of time occupied by the after-effect varied according to the intensity of the light. Thus after a weak light, the unchanged impression lasts longer than with a strong light. A strong illumination is followed by an after impression fading sooner than with a feeble stimulus—the result being that, so far as the retina is concerned, it comes to the same thing whether an intense light acts for a brief time, or a faint light for a longer time

EXHAUSTION OF NERVE OR SENSORY ORGAN.

This line of research has also made it possible to measure the time required for exhausting a nerve or sensory organ. When, for instance, a limited area of the retina has been stimulated for a certain time, and the stimulus has been removed, the after positive effect, due to increased excitation of the parts, disappears, and is followed by a negative effect, due to temporary diminution of the sensibility of the parts, in the form of what is called the negative after-image Suppose, for example, an area of the retina be acted upon for a period of from five to ten seconds, and the stimulus be then removed, the so-called positive after-image vanishes quickly, and the negative after-image, frequently of a complementary colour to that of the exciting cause, appears, and lasts for a short time, gradually fading away as the nervous parts recover from the effects of the stimulus. Similar phenomena may be observed in studying the durations of sensations of tone, which I have frequently perceived in experiments made by myself; but it is more difficult to identify, by description and designation, the after-effects in the case of audition than in the case of vision. Probably it may be found still more difficult to notice these after sensations in the other senses, although in all there is often the experience of a lingering feeling after the cause has been removed, which no doubt has its place in those transient sensations which assist in filling up the spaces, as it were, in our conscious life,

In experiments upon a sensory organ, such as the retina, a little consideration will show that it is almost impossible to ascertain the effect of a stimulus upon a retina which has never before been affected. This difficulty has been felt by all experimenters. Molecular action in such a structure has been in operation from the very beginning, and such action, if of sufficient intensity, must produce a certain effect on the conducting-tract and on the recipient centre. This effect, although of too weak intensity to produce those changes which result in consciousness, must be taken into account in the measurement of the intensity and duration of sensory impressions. Thus the eye has a light of its own due to changes in the retina, although this may never be conscious to us as a luminous impression. This conception of the state of matters in a terminal organ such as the retina, when applied to actions going on in the brain, at once indicates that similar actions, or rather that similar states of unrest, of change, variation, and modification, are going on in these deeper parts which may never result in consciousness, *per se*, but which altogether may have an influence on our mental existence comparable to that of the feeble impressions constantly transmitted to the cerebrum from the viscera, sometimes termed the internal senses.

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* In the following observations I am much indebted to the essays of Mr. James Sully, contained in his volume, 'Sensation and Intuition' (London, 1874).

Relation between Strength of Sensation and Magnitude of Stimulus.

Having shown that sensory impressions are distinctly related to time, the next advance made by physiologists was to prove that there was a relation between the strength of the sensation and the magnitude of the stimulus. Here there are difficulties in explaining what is meant, because language fails. We have no words to discriminate ideas which hitherto have related to two distinct fields of knowledge—the objective and the subjective. To speak of the strength or magnitude of a sensation seems to be using terms applicable only in another region, and quite inapplicable to psychological phenomena, although no one has any doubt in distinguishing the intensity or magnitude of one pain from that of another. There is no difficulty in understanding the phrase-magnitude of the stimulus. A weight of ten pounds is greater than that of one pound, light from ten candles of equal size is more than that given out by one, and the tones of a violin of equal pitch and quality may vary in intensity according to the pressure of the bow on the string. It is difficult, however, to obtain an absolute measurement of variations in sensation, which is, of course, a subjective phenomenon. This can only be done by varying the objective cause, by observing a large number of instances, and by expressing variations in the subjective phenomenon in terms applied to variations in the objective cause. If the average result obtained from a large number of instances indicates any ratio between the magnitude of the stimulus and the subjective phenomenon, then we may conclude that there is a relation between the two.

This mode of inquiry, first originated by Professor E. H. Weber, in his celebrated experiments on tactile impressions (and which were first introduced to notice in this country by Professor Allen Thomson), was afterwards carried out by his colleague Professor Fechner, and has been subsequently elaborated by Professor Wundt. It has led to various remarkable results, the chief of which are (1) that in the case of each sense there is an upper and a lower limit, beyond which the amount of stimulus produces no appreciable difference of effect; and (2) that within this range there is a definite ratio between the stimulus and the amount of the sensation. The upper limit beyond which an increase of external stimulation is not followed by any observable increase in sensational effect was first observed by Professor Wundt. The lower limit has been noted by many observers, and it is indicated in almost every physiological text-book. Now it does not matter much to us, in taking a general view of things, what the limits are, provided we are sure that such limits exist, inasmuch as it indicates another element of proof that psychological phenomena, so far as sensation is concerned, occur within certain physical limits.

Fechner's Investigations.

The next step naturally was to establish the ratio between the magnitude of the stimulus and the magnitude of the sensation. To do this directly is impossible, as any estimation of the amount of sensational effect following a given stimulus would probably be erroneous, because our perceptions are usually qualitative and only rarely, and never absolutely, quantitative. Fechner recognized this fact, and he employed for the solution of the problem various methods by which he measured not sensations themselves, but the amount of discriminative sensibility between two sensations produced by stimuli of unequal magnitudes, and he studied the ratio between the difference of weight and the absolute quantity of the stimulation. By varying the amount of the stimulus in every possible way, he eliminates the chances of error, and arrived at definite results. These results he formulated into a general "psychophysical law," which may be expressed in various ways. Mathematically it may be put, that "sensation increases in proportion to the logarithm of the stimulus." Now "logarithms increase in equal degrees when the numbers so increase that the increment has always the same ratio to the magnitude of the number." It may be put in another way by saying that "the more intense a sensation the greater must be the added or diminished force of stimulation in order that this sensation undergo an appreciable change of intensity." The mode of arriving at some of Fechner's results may be better understood by an experiment which any one can repeat. In the case of muscular sensation, suppose two weights, A and B; we wish to ascertain the least difference between these perceptible by the muscular sense, say when we lift them in the hand. Let it be so arranged that both weights are composed of different pieces, so that the one may be made less or more than the other at pleasure. If A and B be nearly equal in absolute weight, the person on whom the experiment is made will judge them to be of equal weight. Let weights be now added to B until the difference between A and B becomes perceptible, and as a test, let the weights be again removed from B until, in sensational effect, A becomes again equal to B. Let the same experiment be repeated with weights of different absolute amount, and it will be found that there is a distinct ratio between the absolute weight and the weight that had to be added to it or taken from it to produce the least perceptible difference of impression, whatever these weights may be, up to the limits, of course, which I have already noticed. It will always be found that the additional or subtracted weight is one third that of the absolute weight,—a fraction which indicates the degree of intensity of the stimulus required to produce the least perceptible feeling of difference of sensation, and which may be termed the "*constant proportional*" of that kind of sensation. This fraction, in the case of sensibility to temperature, Fechner found to be one third; Rentz, Wolf, and Volkmann arrived at the same fraction with regard to auditory impressions; and various observers have found that in visual impressions it is one hundredth.

Now the intensity of sensation depends on two conditions:—(1) the intensity of the excitation; and (2) the degree of excitability of the sensory organ at the moment of excitation. But suppose the excitability of the organ equal on two occasions, the intensity of the sensation does not increase proportionately to the increase of the excitation. That is to say, suppose we bring into a dark chamber a luminous body such as a candle—it produces a certain luminous sensation; then introduce a second, third, and fourth—the excitation is double, triple, or quadruple; but experiment shows that the increase in the amount of the sensation is much less; in others words, let the stimulus increase from 10 to 100 times, and from 100 to 1000 times, the sensation will be only one, two, and three times stronger. The importance of the discovery of this remarkable law is, that it shows a distinct mathematical relationship between stimulation and sensation. Possibly it may be found to have applications to other psychological phenomena. May it not vary in different animals, and even in different individuals?

CRITICISM OF FECHNER'S METHOD.

It is quite noticeable, however, that, in the case of each sense, the law did not hold good throughout the whole range of variations in intensity of stimulus; and it is not surprising, when we consider the complexity of the conditions, that such should be the case. All of these experiments were made in the case of visual impressions, for example, on the living eye, connected by the optic nerve with the brain; and it is manifestly impossible, as has been remarked by Hermann, "to localize this relationship between sensational effect and variation in amount of stimulus, which has been called the psycho-physical law of Fechner." Between the sensational effect and the first contact of the stimulus there are a series of complicated processes occurring in retina, nerve, and brain, processes undergoing incessant modification by the interchanges between these tissues and the warm circulating blood. In which of these does this relation between stimulus and conscious state occur—in retina, in optic nerve, or in brain? The only method of answering this question, so far as I know, is to examine the effects of stimulation upon these parts separately. It is manifestly next to impossible to do this in the case of the optic nerve and the brain; but by the method pursued by Holmgren in Sweden, and by Professor Dewar and myself in this country, it can be done, so far as the retina is concerned. In carrying out this method, Professor Dewar and I found that light produced a change in the electrical condition of the retina in an eye removed from the head or kept in normal conditions, and we ascertained that the general phenomena of this change corresponded with our sensational experiences of luminous impressions. We were therefore entitled to assume that the change in the electrical conditions of the retina, produced by the action of light, might be regarded as a phenomenon intimately related to those changes in the brain which result in consciousness of a luminous impression. Consequently we had an opportunity of ascertaining whether or not Fechner's law agreed with the effects of a stimulus of light in altering the electrical condition of the retina, and we found that it did so. The inference, therefore, is that the relation between degree or variation in stimulus and the corresponding sensation of a luminous impression is a function of the sense-organ or retina.

MODE OF INVESTIGATING THE SENSORY ORGAN ITSELF.

I may here remark that this mode of inquiring into sensory impressions has by no means been exhausted. The subjective method of observing sensational effect under the stimulus of light from revolving disks, by the contrasting of colours, by comparison of auditory sensations produced by tones of different intensity, pitch, and quality, is always open to the charge that the results may not be due to specific histological structure of the sense-organ, as is almost invariably assumed, but to the structure of the recipient of impressions from the sense-organ, namely the brain. The only way of proving that the effects are due to structural peculiarities of the sense-organ is to examine the effects of stimuli applied to the sense-organ separated from the brain by some method the same as or analogous to ours. If in these circumstances the sense-organ gives results similar to those observed in the phenomena of consciousness, then we may assume that these results are due to specific peculiarities of the sense-organ, and not to the brain. If, on the other hand, the results do not agree, then we must look in the brain for the mechanism by which these different results are produced. Thus I have always held that, as there is little or no histological evidence of complexity of structure in the retina capable of accounting for the theory of Thomas Young regarding the perception of colours, or of the facts of colour-blindness, or of the sensibility of different zones of the retina to lights of different colours, we may have to look to the complex structure of the corpora quadrigemina, cerebellum, or some portion of the cerebral hemispheres for an explanation of these facts. It may be objected that such scepticism simply removes the difficulty a little further back; but I think it better to search for facts than to be content with an hypothesis.

CONCLUSION.

Time will not permit me to discuss other researches in this field of inquiry, nor the interesting speculations which have sprung from them, but I think I have said enough to show the line of advance in this direction.

True it is that apparently the physiological causation of many mental phenomena may be, in its precise nature, inaccessible to direct proof, but it is our duty as physiologists to push legitimate research as far as it will go. I would remark also that such researches are not incompatible with those spiritual ideas, matters of faith and not of science, which are the basis of our most cherished hopes They demand, however, caution in the scrutiny of facts, and judgment in drawing conclusions from them More than in any other kind of scientific labour, perhaps, it is of the utmost importance here to keep the mind unbiassed—a task by no means easy. To maintain a calm unprejudiced attitude to inquiries which seem to demand a change of opinion regarding what was supposed to be final, requires an effort which varies in different persons. Some find it comparatively easy to do so, while others succeed only after a severe struggle Still it is the state of mind which a man true to science ought to aspire to, so that while he will not be blown about by every wind of doctrine, he may be ready to accept what is apparently true when he has had it clearly put before him

In conclusion, let me observe that it would save not a little heart-burning, and might possibly remove acrimony from various scientific and social controversies, could we only remember that it is not very probable that we, in this nineteenth century, have arrived at the final solution of many problems which have puzzled wise men from the earliest times. Probably we have got nearer the truth ; but it is presumptuous to suppose that we have reached the ultimate truth Many hypotheses much in favour at present may turn out to be inadequate Still if they serve as stepping-stones to something better, and to more rational conceptions of the mysterious phenomena about us, they will have done good service. In the mean time it is our duty vigorously to prosecute research in all departments, pushing ahead fearlessly and with that enthusiasm which is the prime mover in all great deeds, so that we may be able to transmit our department of knowledge to posterity not only less burdened with error, but with many additions of truth

BOTANY AND ZOOLOGY.

[For Professor Newton's Address, see page 119]

Notes on the Pandaneæ of the Mascarene and Seychelles Islands.

By I. BAYLEY BALFOUR, *Sc.D.*

The genus *Pandanus* (screw-pine) was shown to have a general distribution throughout the tropics of the Old World, and to reach its western limit on the east coast of Africa. It is very abundantly represented in the islands of the Indian Ocean, and more especially in the Mascarene and Seychelles Islands.

Altogether 19 species are definitely known from these islands, and it is possible that more may exist Of these species Mauritius includes 11, which are all endemic; Réunion has 3 peculiar species, and perhaps a fourth one may be recognized, in Rodriguez only two species, both endemic, are found; whilst the Seychelles group possesses three such species. In addition to those which are endemic, a Madagascar species, *P utilis*, is generally cultivated for the sake of its leaves, and *P. odoratissimus*, of Eastern origin, is also found.

The difficulties in the way of the diagnosis of species were pointed out from the scantiness and imperfection of the material as yet sent to this country. The leaves afford very little character, and it is from the fruit that specific distinctions are mainly obtained Hitherto the stigmas have afforded the chief characters ; but the author showed that many important diagnostic marks might be obtained from the endocarp and its relations to the mesocarp.

On the Evolution of Sex in the Vegetable Kingdom. *By* G. S. BOULGER.

This paper was an attempt to illustrate Mr. Herbert Spencer's law of increasing heterogeneity by the various sexual processes in the vegetable kingdom. Mention having been made of the probably asexual Protophyta, Thwaites' identification of conjugation with reproduction proper, made in 1848, was mentioned, and a summary given of the sexual classification of the Thallophytes proposed by Sachs (Lehrbuch, 4th edition) and adopted by Professor Dyer (Quart Journ Micr Sci.), in which they are grouped as Protophyta, Zygosporeæ, Oosporeæ, and Carposporeæ. The types *Pandorina*, *Mesocarpus*, *Spirogyra*, and *Podosphæra* were taken as indicating sexual transition between these groups, and Sachs' description of the essential nature and elements of sexual reproduction quoted. The difference between the sexes as manifested previous to the formation of the elemental 'sperm' and 'germ' cells was then traced in the various groups, being greater and manifested earlier in the more highly organized groups.

Œdogonium, *Vaucheria*, *Phycomyces*, *Coleochæte*, and *Nemalion* were alluded to in this connexion, and following the pedigree sketched by Sachs (Lehrbuch, 3rd edition) the 'secondary sexual organs' were traced through the Florideæ to the ancestral Cormophyte and to the 'heterosporous Pteridophyta,' near to which he places the Cycadeæ, the lowest type of Phanerogam. The homology between the sexual organs of Phanerogams and Cryptogams was pointed out, and Hildebrand's classification of the sexual arrangements explained.

In this connexion the terms 'apertiflorous' (open-flowered) in opposition to 'cleistogenous,' 'approximate,' and 'distant,' with anthers near to or remote from the stigma, and 'homostylia,' were proposed by the author for adoption. It was then attempted to base the phylogenetic arrangement of sexual forms (the chief subject of the paper) on the law of economy of nutrition, the advantageousness of cross-fertilization producing diœcism and various intermediate stages from an original hermaphroditism. Diœcism was first traced through monœcism and monœcious polygamy, *Fragaria*, *Rumex*, and a reverting sport of *Begonia frigida* being quoted. The diœcism of the English holly has probably been reached from diœcious polygamy, as in the American forms, through an intermediate monœcism, and the monœciously or triœciously polygamous genus *Catasetum* points to the origin of the latter form from the former probably through an intermediate diœcious polygamy. Diœcism may possibly arise also from dimorphism, which may be monœcious, as in *Dianthus caryophyllus* and *D plumarius*, or diœcious, as in some Primulas.

Dimorphism probably originates in 'biseriate' stamens, trimorphism in 'triseriate,' but the diœcious dimorphism of *Lythrum thymifolia* would seem to arise from triœcious trimorphism by suppression. Among the Compositæ the transitions are easy from the 'equal polygamy' of Linnæus, through 'superfluous polygamy,' to 'frustraneous' on the one hand and 'necessary' on the other, from either of which monœcism and diœcism may arise, as in *Carduus arvensis*, *Petasites*, and *Antennaria*. The variety, increasing complexity, and homology of the sexual arrangements, the abundant links, and the abhorrence of the sexual union of nearly related cells are the theme of the whole paper.

Two Monstrosities of Matricaria inodora.

By Professor ALEXANDER DICKSON, *M.D.*

1st. Where the florets of the capitulum were replaced by stalked secondary capitula, some of which were in turn again similarly compound. That the secondary capitula really resulted from transformed florets was interestingly shown by the presence on the stalk of many of the outer secondary capitula of a ligulate corolla with its base embracing the axis.

2nd. Where many of the florets of the ray presented a narrow ligulate lip directed inwards, these internal lips conniving more or less over the central disk. At first sight this anomaly seemed to simulate the condition in Compositæ Labiatifloræ; but so far as Dr Dickson's examinations as yet went, it would appear that the smaller lip was placed laterally to the normal line of non-union of the ligulate corolla, and therefore was not a mesial structure compressed to the inner lip of the floret in Labiatifloræ.

Laticiferous Canals in Fruit of Limnocharis Plumieri.

By Professor ALEXANDER DICKSON, *M.D.*

Dr Dickson showed that unusually large laticiferous canals could easily be demonstrated shining through the epidermis of the flat surfaces by which the numerous carpels are in opposition to each other.

On the Occurrence in Ireland of Nuphar intermedium, *Ledeb.*

By A. G. MORE, *F.L.S., M.R.I.A.*

While staying with some friends at Crombyn, in West Meath, I noticed on the borders of a small shallow lake, on peaty ground, some water-lily leaves which at once drew attention from the small size of their leaves and especially with their basal lobes standing apart or widely apart. My friend Mr Preston Battersby, of the Royal Artillery, most kindly instituted a close search, and succeeded at last in finding one blossom, from which, together with the leaves, I have been enabled to identify the plant as *Nuphar intermedium*, Ledeb., var. β *Spennerianum*, of Hartman's 10th edition of the 'Handbok i Skandinaviens Flora' (Stockholm, 1870), vol. i. p. 86.

Our plant is also, I presume, identical with Dr Syme's so-called variety "β. *minor*" of *Nuphar luteum*, but the stigma of the single flower gathered has 15 rays. Still the characters of the leaf bring it rather nearer to var. *Spennerianum* than the typical form of Ledebour's *N. intermedium*.

A. G. MORE, F.L.S., exhibited *Zostera nana* from Carnarvonshire.

Professor W. R. M'NAB, M.D., exhibited *Choreocholax polysiphoniæ*, Reinsch.

Notes on the Structure of the Leaf in different Species of Abies.

By Prof. W. R. M'NAB, *M.D.*

On Circinnate Vernation of Sphenopteris affinis *from the earliest stage to completion, and on the discovery of* Staphylopteris, *a Genus new to British Rocks.* *By* C. W. PEACH, *A.L.S.*

The author stated that he had found *Sphenopteris affinis* in black shale at West Calder, near Edinburgh, in circinnate vernation from its earliest state to the completion of the plant, and thus had an opportunity of seeing this beautiful fern in all its various stages of growth, showing the many variations it assumes and from which, when so found, no doubt several species have been made.

It is rather plentiful at West Calder, Slateford, Burdie House, Burnt Island, and other places around Edinburgh; he, however, had not found it in circinnate vernation in any other locality than the first mentioned.

He next exhibited and described specimens of *Staphylopteris*, also from West Calder, and said the plant was a new genus to British rocks; that he had met with it first sparingly in 1874, and in the present year in some abundance there, especially in one slab. It is something like *Staphylopteris Worthenii* of Leo Lesquereux, figured in vol. iv. of the Geological Survey of Illinois, from "the shale of the subconglomerate coal of Arkansas." it, however, differed from that species, first, in not showing like a star around a central point; in having no sporanges; and the flower-like parts instead of only "*apparently resting on*," are *actually attached* in pairs, hanging in a drooping manner, to small branches. As well as the one mentioned, he strongly suspected that he has another species from the same locality. Several species have been found in the rocks of Arkansas; all, however, differ from the British one.

The author expressed his obligations to Mr. R. Etheridge, jun., for first calling his attention to the American work, and to Prof. Balfour for his kind notice in the 'Transactions of the Botanical Society of Edinburgh,' vol xii part i page 170, both proposing that it should "bear the name of the finder" He thought it right to state that wherever he found *Staphylopteris*, the *Sphenopteris affinis* more or less accompanied it, however, the latter was most often found without *Staphylopteris*. As well as at West Calder, *Staphylopteris* has been found at Slateford by the Officers of the Geological Survey and by Mr D J Brown at Straiton, all near Edinburgh, and all in the Calciferous Sandstone series

A large series of *Sphenopteris* and *Staphylopteris* were exhibited by the author with drawings for illustration

On some of the Physiological and Morphological Features seen in the Plants of the Coal-Measures. By Professor W. C. Williamson, *F.R.S*

Proceeding from the starting point of the facts recorded in the communication made to the Geological Section *, the author brought before the Biological Section some morphological facts He showed that even in young twigs of *Lepidodendron* the bark consisted of three very distinct layers, viz —an inner parenchyma, a middle prosenchyma of considerable proportionate thickness, and an outer parenchyma of which the leaves were expansions The innermost portion, the inner parenchyma, certainly represents a plane of genetic activity, along which the multiplying cells add new layers of vessels to the exterior of the vascular cylinder on its inner surface, as it apparently increases as the number of parenchymatous cells in the opposite directions Externally to this parenchyma is the prosenchymatous layer, into which the inner parenchyma passes somewhat gradually, but which outwardly becomes a modified mass of prosenchymatous fibre, composed of very long and narrow prismatic cells At the first glance this layer looks like a phellem or corky layer, but its origin is a different one. Its genetic plane is at its outer surface, instead of occupying the position of the phellogen of living barks The cells at this point become elongated radially into long fusiform ones, which soon become subdivided by a regular series of vertical cell-walls, all of which are parallel to each other and to the external surface of the stem Subsequently each one of these parallel cells becomes irregularly subdivided into a cluster of cells, the partitions of which are vertical to the primary series In this manner, apparently, additions are made on the inner side to the prosenchymatous layer, and on the outer one to the subepidermal parenchyma It thus becomes evident that the bark of each of the Lepidodendroid stems possesses two parallel planes of genetic activity.

It is obvious that *Calamites* certainly possesses the innermost of these genetic planes; and as the author's arborescent specimen exhibits no indication that the second or prosenchymatous layer has been increased from within, it becomes more than probable that when yet more perfect specimens are discovered the second or outer genetic plane will be found to be identical in all respects with what is seen in the *Lepidodendra*

The author concluded by calling attention to the fact that amongst a large number of the coal plants their most specialized and characteristic type features were best seen in their young state, the advance from youth to maturity being one from specialized to generalized forms, the result of which was, that the author found it almost impossible to identify detached fragments of wood or bark, and hence he regarded all attempts to establish genera and species upon such fragments as absurd.

On Gigantic Land-Tortoises and a Freshwater Species from the Maltese Caverns, with observations on their Fossil Fauna. By A. Leith Adams, *F.R.S., Professor of Zoology, Royal College of Science, Dublin.*

The author exhibited and made a few observations on bones of gigantic tortoises collected by Admiral Spratt and himself in the Maltese Caverns.

During the five years he was engaged in exploring the rock-cavities of Malta, among other fossil remains, he discovered several fragments of bones of gigantic Chelonians, one of which rivalled in dimensions any of the recent or extinct species hitherto reported from the Mascarene and Galapagos Islands. The remains were found in conjunction with bones and teeth of the dwarf elephants and gigantic dormice; and whilst remains of the Proboscidians and Rodents were extremely abundant in certain rock-cavities he examined, and the Chelonians were also well represented, it was a noteworthy fact that no traces of large Carnivora were met with. This absence of the order, excepting the tooth of a small *Canis*, he supposed accounted for the presence of the large helpless tortoises, as obtained also in the Galapagos and Mascarene Islands.

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* *Suprà*, p. 98.

The largest of the Chelonians rivalled in dimensions the *Testudo elephantopus* and *Testudo ephippium*, and showed some affinities with the latter, but was generally distinguishable from any recorded species from these islands by a marked robustness of the bones, on which account he proposes to name it *Testudo robusta*. A smaller species, distinguishable also, morphologically, from the preceding, he proposes to name after Admiral Spratt; whilst a few bones of a small freshwater tortoise were indistinguishable from the same parts of the *Lutremys europæa*, which is still not uncommon in the south of Europe and in certain islands of the Mediterranean.

The author was inclined to believe that the Maltese-cavern fauna belonged to a late Pliocene rather than a Pleistocene period, such as that exhibited by the Sicilian caverns, to wit, the Caves of Palermo; and that, although the *Hippopotamus Pentlandi* and smaller forms are both represented in Malta, Sicily, and Crete, the absence of traces of the dwarf elephants and gigantic dormouse in the two latter situations, and the presence of the *Hyæna crocuta*, *Elephas antiquus*, and large *Felidæ* in Sicily, seem to point to faunas of two different epochs. Indeed, in the case of the Maltese deposits, it would appear, in some instances at all events, that the animal remains of the fissures had been derived from older beds which were broken up during the submergence of the area. But as the Maltese rocks were Miocene and the uppermost had been supposed to indicate the presence of Pliocene Invertebrata, it was clear that the red soil and clay which formed the matrix in which the above animal remains were found, in the rock rents, could not be more ancient than a later Pliocene.

He strongly advocated further explorations of the islands of the Mediterranean in quest of fossil remains, and stated that there was still much to be done in Malta.

On the Arenaceous Foraminifera collected in the 'Valorous' Expedition.
By Dr. W. B. Carpenter, *C.B., F.R.S.*

Further Researches on the Nervous System of Antedon rosaceus (Comatula rosacea, *Lamk.*)
By Dr. W. B. Carpenter, *C.B., F.R.S.*

Remarks on the Anatomy of the Arms of the Crinoids.
By P. Herbert Carpenter, *B.A.*

On Delphinus albirostris.
By D. J. Cunningham, *M.D.*

Experiments on the Formation and Growth of Artificial Silica Cells.
By Prof. Ferdinand Cohn.

On Spontaneous Evolution and the Germ Theory. *By* N. Carmichael, *M.D.*

The Biological Results of a Cruise in H.M.S. 'Valorous' to Davis Strait in 1875. *By* J. GWYN JEFFREYS, *LL.D., F.R.S.*

A preliminary Report on this subject was presented to the Royal Society, and has been published in their 'Proceedings,' vol. xxv. p. 177. The author gave an account of the voyage (which was undertaken by him in consequence of an application made by the Council of the Society to the Admiralty) and of the biological results, more especially with respect to geographical distribution and geology. The author treated of the Mollusca; and Professors Allman and Duncan, Dr. M'Intosh, the Rev. A. M. Norman, Dr. Carpenter, and Professor Dickie contributed notices of other departments of the marine fauna and flora.

A Double Dilemma in Darwinism. *By* the Rev. F. O. MORRIS.

Notes on Oceanic Deposits and their Origin, based on Observations made on board H.M.S. 'Challenger.' *By* JOHN MURRAY.

On the new Casts in the Hunterian Museum. *By* Prof. J. YOUNG, *M.D.*

ANATOMY AND PHYSIOLOGY.

[For Dr. M'Kendrick's Address, see page 126.]

On the Development of the Proto-Vertebræ in Elasmobranchs. *By* F. M. BALFOUR, *B.A., Fellow of Trinity College, Cambridge.*

The mesoblast in Elasmobranchs arises as two independent plates, each of which becomes divided into two layers, a somatic and a splanchnic. In the dorsal part of each plate a series of transverse slits arises, which serves to distinguish a dorsal or vertebral portion of the plate from a ventral or parietal. A cavity is next formed between the two layers of the plate, which is continued quite to the summit of the vertebral part. Still later the segmented vertebral part of each plate, with its enclosed cavity, becomes separated from the parietal part and forms the muscle-plates. Each of these is a somewhat rectangular body, formed of two layers, enclosing between them part of the original body-cavity. The inner of these two layers soon buds off cells to form the rudiments of the vertebral bodies, and itself is transformed into longitudinal muscles; the outer layer of the muscle-plate becomes converted into muscles at a considerably later period.

On the Changes in the Circulation which are induced when the Blood is expelled from the Limbs by Esmarch's Method. *By* H. G. BROOKE, *B.A.* (*Lond.*), *and* E. O. HOPWOOD, *B.A.* (*Oxon*).

The authors stated that the object of the experiments was to observe the pulse during and after the expulsion of blood from the limbs. Healthy young men were experimented on, and the expériments were made one or two hours after a light meal. The pulse was counted with the aid of a watch, and its form recorded by means of the sphygmograph. The person experimented on was stripped and recumbent. Normal pulse-rate and sphygmographic movements were recorded; and afterwards one leg was bandaged from below upwards. During bandaging, pulse-rate was observed, and immediately bandaging was complete further sphygmographic tracings were taken. This was repeated with the other leg. After a short time both bandages were suddenly let go, and at the same instant pulse-rate and sphygmographic movements were again recorded.

As the result of their observations, the authors state that—

1. During bandaging of the first lower limb, the pulse-rate increases, and afterwards (generally after a very short interval) falls to about the normal.

2. During bandaging of the second lower limb, the pulse again quickens its pace, returning almost to the normal, but sometimes remaining a few beats above the normal.

3. When both bandages are suddenly let go, there is at once a marked acceleration of pulse-rate, but of brief duration.

The authors point out the changes which bandaging and unbandaging must have upon the disposition of the blood in the circulating system. Thus, on bandaging, the arterial blood is driven from the limbs bandaged into the arterial system of the trunk, head and neck, and upper extremities, raising the pressure all over the system; while the venous blood, together with the lymph, are also driven into the rest of the body from the compressed limbs, but are only able to affect the pressure in the trunk, head, and neck, being excluded by valves from the upper extremities. Hence the general venous pressure will have a relatively larger increase than the general arterial pressure.

Again, on unbandaging, the arterial blood rushes down the lower limbs to fill the previously obliterated vessels, thus diminishing the general pressure of the arterial system, while no such reflux of the venous blood is possible on account of the interposed valves of the veins. Hence, while the arterial pressure is diminished suddenly, the venous remains, for the moment, as it was; that is to say, the general venous pressure will experience a relatively less diminution than the general arterial pressure.

Now, comparing the conditions on bandaging and unbandaging, it will be seen that, *in both cases, the relative difference normally existing between arterial and venous pressures on the two sides of the heart is diminished*, on bandaging by approximating the venous to the arterial pressure, on unbandaging by approximating the arterial to the venous pressure. May we not, the authors suggest, seek in this coincidence of conditions an explanation of the somewhat unexpected similarity of effect on bandaging the lower limbs and on loosing the bandages?

In the course of the discussion which followed, Professor Kronecker, of Leipzig, pointed out that the addition of a large quantity of lymph to the blood on bandaging, by altering the composition of the blood, might well be supposed to affect the heart's rate, since the heart is now known to be very sensitive to qualitative changes in the fluids bathing it.

On the Morphology and Histology of the Nervous System of Antedon rosaceus (Comatula rosacea, *Lamk.*). *By* Dr. W. B. CARPENTER, *C.B., F.R.S.*

On a Hypothesis of the perception of Articulate Speech. By Dr. CASSELLS.

On the Morphological Relations of the Lower End of the Humerus.

By Professor CLELAND, *M.D., F.R.S.*

In this communication it was pointed out that the torsion of the humerus spoken of by more than one writer has no existence in nature, and that the limb is developed in its morphological position. While the radius is morphologically anterior to the ulna, the anterior, posterior, external, and internal aspects of the humerus have morphological relations exactly corresponding with those names, so that the flattening of the lower end of the humerus is not a commencement of the expansion which results in two bones in the forearm. The radius does not belong to the outer side of the humerus, nor the ulna to the inner side; but the radius is in front of the humerus, the ulna behind it, and the limb is in its morphological position when the forearm is in semipronation.

On a Hydrocephalic Skull, and on the Duplicity of the Temporal Ridge.

By Prof. CLELAND, *F.R.S.*

On the Spinal Nervous System of the Cetacea. *By* D. J. CUNNINGHAM, *M.D.*, *Senior Demonstrator of Anatomy, Edinburgh University.*

At the outset of my investigations into the anatomy of the spinal nervous system of the Cetacea, I endeavoured to discover whether any anatomist had described the arrangement of these nerves. This was no easy matter, so little had been written on the subject. H. Rapp ('Die Cetaceen,' Stuttgart, 1837) states that, "with respect to the course of the spinal nerves (of the Cetacea) there are no researches," and Stannius ('Lehrbuch der Vergleichenden Anatomie,' Zweiten Theil, 1846, p. 393) simply mentions that "in the Dolphin a nerve-trunk proceeds out of the lumbar plexus, the branches of which are intended for the muscles of the rudimentary pelvis, and for the external genital organs and their muscles, as well as for the region of the anus." Indeed it was not until I had finished my investigation that I discovered that Swan, in the "Table of Contents" or Introduction to his work upon the 'Comparative Anatomy of the Nervous System,' published in 1835, gives a short account of the whole nervous system of the porpoise. I believe, however, that besides extending his account very materially, I am able to give additional results, and I have taken care to have all my dissections illustrated by drawings, whilst he, with his wealth of plates of the nervous system of other animals, does not give one of the nervous system of the Cetacea.

I may mention that the following results are derived from the dissection of four members of the Cetacean group, viz. three porpoises and one dolphin.*

Spinal Cord.—The spinal cord is surrounded and supported on all sides by the dense rete mirabile, which may be looked upon as performing a threefold function: (1) it constitutes a soft pliable packing material, by means of which the cord is protected from shocks; (2) it maintains a uniform warmth around this important and delicate nervous centre by keeping it constantly bathed, as it were, in warm arterial blood; (3) and lastly, as Professor Turner has pointed out (Trans. Roy. Soc. Edinb. vol. xxvi. p. 233), it subdivides the arterial stream, and equalizes its force before it reaches the brain and spinal cord.

In the porpoise the spinal cord extends from the margin of the foramen magnum to a point corresponding to the interval between the 6th and 7th lumbo-caudal vertebræ, and opposite to the foramina of exit of the 27th pair of spinal nerves. It presents two enlargements—one in the cervical, and the other in the lumbar region. The former of these is connected with the nerves which go to form the cervical and brachial plexuses, and the latter with the nerves which supply the genital organs and the muscular apparatus of the tail. Between these enlargements the cord is of uniform diameter, and the lumbar swelling tapers away in a fusiform manner into the filum terminale.

Roots of the Spinal Nerves.—The direction and length of the nerve-roots and the size and position of the ganglia vary in the different regions of the spine.

The nerve-roots which proceed from the cervical and lumbar enlargements of the cord are closely crowded together, whilst in the dorsal region they are placed at considerable intervals from each other. Those arising from the lumbar swelling are very long, tortuous, or curly, loosely bound together by lax connective tissue, and they constitute the cauda equina. They pass directly backwards to reach their respective foramina of exit. The dorsal and cervical nerve-roots are much shorter, and the former are directed outwards and backwards, whilst the latter, with the exception of the first three which pass directly outwards, take a course outwards and forwards.

In all the regions the superior nerve-roots are smaller than the inferior—thus constituting a marked contrast to most mammals, in which the reverse of this arrangement holds good. Nowhere, however, is this difference in size so marked as in the cauda equina, in the last nerves of which the superior root is half the size of the inferior, and in some places so delicate that when stripped of the loose connective tissue which surrounds it, it resembles (in the porpoise) a fine thread or hair. From this fact we must not conclude that sentiency is dull in the Cetacea, for as the animal tapers towards the tail the amount of skin to be supplied with sentient fibres is small in comparison to the huge muscular masses to be supplied with motor filaments. In the cervical, dorsal, and upper lumbar regions where the cutaneous surface is extensive the superior roots attain a size only slightly smaller than the inferior roots.

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* A young specimen of *D. albirostris* (*vide* Proc. Zool. Soc. 1876, p. 679).

Spinal Nerves.—In the lumbo-caudal region of the vertebral column of a porpoise or other cetacean, the intervertebral foramina correspond to the intervals between the laminæ of contiguous vertebræ, and consequently lie on a higher horizontal plane than the transverse processes. As we approach the dorsal region, however, a rudimentary pedicle begins to show itself, and this becomes more and more marked as we pass on towards the cervical region. In the cervical and dorsal regions, therefore, the intervertebral foramina occupy a more ventral plane, being situated between the pedicles and inferior to the transverse processes. It follows from this that the removal of the great extensor muscle in the lumbo-caudal region displays the whole spinal nerve issuing from the spinal canal, whilst in the dorsal and cervical regions it only exposes the superior divisions of these nerves passing upwards between the pedicles.

Cervical Nerves.—These are eight in number, and, owing to the fusion or close opposition of the vertebræ in this region, they are closely crowded together. Each nerve divides into a superior and inferior division. The superior divisions supply the muscle and skin on the superior aspect of the neck, and are in some cases (*e.g.* dolphin) joined together by communicating branches which lie close to the vertebræ. The first three of the inferior divisions join together, so as to form a cervical plexus, whilst the remaining five, together with the first dorsal nerve, and in some cases a small twig from the second dorsal nerve, enter into the formation of the brachial plexus. The chief branches of the brachial plexus are those which correspond to the musculo-spiral, median, and ulnar nerves in man. There is no circumflex nerve.

Dorsal Nerves.—The superior divisions of these nerves join together in a plexiform manner. Well-marked communicating branches pass between the various superior trunks, and connect them with each other. A longitudinal cord or plexus is consequently formed. The distribution of the inferior divisions is similar to that of the same nerves in other mammals.

Lumbo-caudal Nerves.—The arrangement of the spinal nerves posterior to the dorsal region is different from that of any other group of mammals (excepting perhaps the Sirenia) with which I am acquainted. The final cause of this is obvious, it is an adaptation of the nervous system to suit peculiarities in the muscular construction of these animals. In other mammals powerful inferior extremities are developed for the purpose of locomotion, and consequently the inferior divisions of the lumbar and sacral nerves are large as compared with the superior divisions, and they are thrown into plexuses to supply the muscles which act upon these limbs. In the Cetacea, on the other hand, lower limbs are absent so far as locomotion is concerned. The tail is the great organ of progression, and the muscles which work it are developed equally above and below the transverse processes of the vertebral column. In consequence of this, the superior divisions of the spinal nerves have as important a part to play in the supply of the muscles of the chief organ of locomotion as the inferior, seeing that it falls to them to give branches to the extensor muscles, whilst the latter have as their office the supply of the flexor muscles. The result of this is, that the superior and inferior divisions of the lumbo-caudal nerves in the Cetacea are very nearly of equal size. To insure the proper nervous supply of the four great muscular masses which work the tail, two great longitudinal cords or trunks are formed by the spinal nerves on each side of the vertebral column—one superior and formed by the junction of the various superior divisions, and the other inferior, and formed by the union of the inferior divisions. The first of these commences towards the middle of the dorsal region, but even in the cervical region a tendency to a similar arrangement is exhibited. The inferior longitudinal cord begins further back, at a point corresponding to the eleventh lumbo-caudal vertebra. Posterior to this point, therefore, we have arranged around the vertebral column four great nervous cords—two of which are superior, and situated one on each side of the vertebral spines, and two inferior, and placed one on each side of the vertebral bodies below the transverse processes. They are continued back to the tail, and their chief function is to supply the four great muscles which act on the tail. Sensory filaments, however, are also given to the skin.

The first eleven of the inferior divisions of the lumbo-caudal nerves do not enter into the formation of the great inferior cord. They correspond to the lumbar and sacral nerves in man. The large internal pudic nerve takes origin from the more posterior of these.

Recent additional Observations on the Physiological Action of Light. *By* Prof. Dewar, *F.R.S.E.*

On the Action of Vanadium upon the Intrinsic Nervous Mechanism of the Frog's Heart. *By* Prof. Arthur Gamgee, *F.R.S.*, *and* Leopold Larmuth.

Method of Experiment.—A frog's heart was arranged with an artificial circulation, the blood (*i.e.* rabbit's serum) passing from a reservoir of given height through the auricles, ventricle, and *bulbus aortæ*, and being allowed to trickle back into the reservoir down the sides of a glass rod, so as to be exposed in a thin film to the air. In the course of this artificial circulation a mercurial hæmodynamometer was interposed, arranged so as to record its movements on a blackened cylinder. Before taking a tracing the outlet of the blood from the circulating system back into the reservoir was obstructed, thus causing the mercury in the distal manometric limb to rise and oscillate. Normal tracings were first taken, then the serum was mixed with a solution of a sodium salt of vanadium ($NaVO_3$, or $Na_4V_2O_7$, or Na_3VO_4), and other tracings taken at intervals. When the effects of vanadium-poisoning were well advanced the vagus nerve was stimulated in certain cases and the effects noted. In other cases atropin-poisoning was induced prior to mixing the serum with the salt of vanadic acid.

Results of Experiments.—When vanadized serum flows through a beating frog's heart (being present in a proportion of ·008 per cent. of V_2O_5) the force of ventricular systole is much diminished, the ventricle passes into persistent contraction for a time, while the auricles pulsate as usual or somewhat enfeebled. If the proportion of vanadium were twice as large, the ventricle stops writhing one or two minutes in a state of rigid contraction, in which it continues for a long time, often, however, relaxing again before death.

When so contracted, excitation of vagus, sufficient to stop the auricles, has no effect on the ventricle.

The previous administration of atropia does not in the slightest modify the above results.

On the Difference in the Poisonous Activity of Phosphorus in Ortho-, Meta-, and Pyrophosphoric Acids. *By* Prof. Arthur Gamgee, *F.R.S.*, John Priestley, *and* Leopold Larmuth.

In their experiments the authors made use of frogs, rabbits, and dogs, and the sodium salts of the phosphorus acids investigated were introduced into the system either subcutaneously or by venous injection. The salts used were trisodic orthophosphate, tetrasodic pyrophosphate, and sodic metaphosphate, the standard solutions being made to contain the same amount of phosphorus calculated as P_2O_5.

As the result of their experiments the authors state:—

1. That trisodic orthophosphate is physiologically inactive.

2. That sodic metaphosphate is a poisonous substance, but not so poisonous as pyrophosphate of sodium.

3. That tetrasodic pyrophosphate is a body of great poisonous activity, inducing death without materially affecting the irritability of voluntary muscles or of nerves. It exerts an action on the spinal cord and medulla oblongata not unlike that exerted by sodium salts of vanadic acid. On the heart its action is similar to that of salts of vanadic acid. On general nutrition and on the alimentary canal (when any action resulted) the effects were like those of poisoning by phosphorus, viz. fatty degeneration of kidneys, muscular tissue of heart and of liver on the one hand, and hæmorrhagic infarctions and brown patchy congestion of the alimentary mucous membranes. When introduced into the alimentary canal fatal results never followed, this being probably due to rapid elimination.

On the Action of Pyrophosphoric Acid on the Circulation.

By Prof. ARTHUR GAMGEE, *F.R.S.*, JOHN PRIESTLEY, *and* LEOPOLD LARMUTH.

The authors described experiments on rabbits and frogs in which sodium pyrophosphate was introduced into the system, chiefly by venous injection. They discovered in rabbits a twofold change in the circulation, occurring within 6–25 seconds after injection of the drug, viz. (1) a fall in blood-pressure and (2) a marked slowing of pulse-rate, which they believe they have proved to be due to an action on the vaso-motor centre in the medulla oblongata and an action on the intrinsic motor mechanism of the heart respectively.

On the Brain of the Canidæ. *By* ROBERT GARNER, *F.L.S.*, *F.R.C.S.*

The author infers, drawing his conclusions from the measurements of the capacity and from casts of the interior of the skulls of different dogs, that the size of the brain does not very closely correspond with the size of the animal. He is also disposed to argue for the derivation of our domestic dogs from one or more wild dogs; but of the more remote origin of the latter he does not propose to treat. From the table it will be seen that no dog has so large a brain as the wolf, or one so small as the jackal, from both which animals he has been supposed to have been domesticated; his brain seems specific in size. Though Mr. Darwin has shown that the large tame rabbit has a smaller brain than the wild one, yet we could hardly suppose that the dog, if he were a domesticated wolf, would have his brain so diminished, the circumstances of the two cases differing very widely. For similar reasons, if either the wolf or the jackal must be assigned as the source of the domestic dog, perhaps preference must be given to the latter. Little account need be taken of the likeness often seen between these different animals, or of the similarity of the cerebral folds, any more than of the corresponding circumstances in the Felidæ.

Though neither the size of the brain nor the intelligence of the dog increase in the exact ratio of the size of the body, yet the two former seem to correspond better to each other. In large dogs the skull, as a whole, rather than its brain-cavity increases, and this for muscular attachment, size of teeth, &c. But it is not easy to advance further and connect the various powers of dogs with any peculiarity of brain organization. In dogs with fine scent, as the hound, the rhinencephalon is elongated or enlarged and the whole brain also lengthened, and this throws back the three arched folds which are situated over the fissure of Sylvius; the smaller dogs, noted for acuteness of smell as well as sagacity, as the terrier, may have a short but deep rhinencephalon, fuller convolutions, and the arched folds more upright. A distinct inner and anterior lobule is seen in front of the upper transverse sulcus, as well as in the hog, sheep, and horse, but little developed in the cat, where smell is less acute; in the sheep it is covered with pigment like the olfactory nerve, and it appears to be the terminus of the inner root of the nerve. The above description comprises most of what is seen on the surface of the brain, and the elongated and simple folds, of which, however, the upper one is bifurcated before and behind, somewhat correspond with Mr. Swan's later dissections, obscure as is his text; there is, however, a superadded tract bordering the longitudinal fissure on each side, connected with the inner surface of the hemisphere, and bounded in front by the transverse or crucial sulcus, also forming behind an occipital portion lying under the supraoccipital lamina In these different convolutions there are certainly minor variations in different dogs

When we see that the brain of the dog is no larger and not more convoluted than that of the sheep, we must infer that he owes his sagacity in a great measure to the training and companionship of his master But no doubt he had its germs by nature, together with fine scent, fleetness, watchfulness, and hunting propensities, he hence became, as Cuvier expresses it, ' la conquete la plus complete, la plus singuliere et la plus utile que l homme ait faite

In the Table several of the above facts will be manifest, for instance, the Newfoundland dog though it was so sagacious as to rescue a drowning man at Southport, and though the weight of its body would have been four or five times as much as that of one of the small terriers, had its brain only about one fifth larger than these last

The capacities of the skulls were ascertained by measuring the interiors by means of sand, and reducing to the equivalents of the natural contents

	Length of Skull	Weight of Brain
	inches	drams
Sheep-dog	$6\frac{1}{2}$	$20\frac{4}{8}$
Old male Trentham Fox-hound	$8\frac{1}{2}$	$29\frac{2}{8}$
Setter	$7\frac{1}{4}$	$26\frac{1}{8}$
Mastiff	$8\frac{1}{3}$	$26\frac{1}{8}$
Retriever or large Spaniel	6	$25\frac{6}{8}$
Colly	8	$25\frac{1}{8}$
White Bull-dog	6	24
Newfoundland	$8\frac{1}{4}$	24
Greyhound	7	$23\frac{3}{8}$
Fox-like Mongrel	6	$23\frac{1}{8}$
Drover s-dog	6	22_{8}
Young Bull-terrier	$5\frac{1}{2}$	$21\frac{6}{8}$
Smooth Terrier, female	$4\frac{1}{2}$	20
Rough Terrier	$5\frac{1}{4}$	$19\frac{6}{8}$
Small Spaniel	$4\frac{1}{2}$	$18\frac{1}{8}$
Lap-dog	$3\frac{1}{4}$	18
Rough Terrier female	$5\frac{3}{4}$	17
European Wolf		$41\frac{7}{8}$
Indian Jackal		$15\frac{4}{8}$
English Fox		$13\frac{4}{8}$
Arctic Fox		$13\frac{4}{8}$

On the Unwholesomeness of Flesh Diet in Tropical Climates
By C O GROOM NAPIER.

Über die Physemarien (Haliphysema *und* Gastrophysema), *von* ERNST HAECKEL.

Diese kleinen Zoophyten, welche auf dem Meeresgrunde festsitzend leben, gehören zu den altesten und einfachsten unter allen Metazoen und stehen in erwachsenem Zustande unter allen Thieren der *Gastrula*-Form am nachsten *Haliphysema* ist zuerst von Bowerbank als eine kleine Spongie, *Gastrophysema* hingegen (unter dem Namen *Squamulina scopula*) von Carter als ein Rhizopode beschrieben worden. Beide Genera zusammen bilden eine besondere kleine Klasse von Zoophyten, welche der Vortragende *Gastraeaden* nennt, und welche weder mit den Spongien noch mit den Hydroiden vereinigt werden konnen, da sie die unterscheidenden Charaktere beiden in sich vereinigen.

Eine ausfuhrliche, von 6 Tafeln begleitete Abhandlung uber diese Gastraeaden hat inzwischen Professor Haeckel veroffentlicht in der 'Jenaischen Zeitschrift für Naturwissenschaft,' vol. xi. Heft i., 20 Marz 1877. Separat-Abdruck in den 'Studien zur Gastraea-Theorie.'

On the Dynamics of the Racial Diet in India. *By* Surgeon-Major JOHNSTON.

On the Action of Alcohol on the Brain.

By CHARLES THOMAS KINGZETT, *F.C.S. London and Berlin.*

The question of what becomes of alcohol taken into the system has been extensively studied.

Thudichum was the first to determine quantitatively the amount of alcohol eliminated by the kidneys from a given quantity of alcohol administered, and the result which he obtained was sufficient in itself to disprove the "elimination" theory at that time widely prevailing.

Dupré and many others continued these researches, from which, to use Dupré's own words, we may fairly draw three conclusions (see 'Practitioner,' March 1872, being abstract of a paper communicated to the Royal Society):—

(1) The amount of alcohol eliminated per day does not increase with the continuance of the alcoholic diet; therefore all the alcohol consumed daily must of necessity be disposed of daily; and as it is certainly not eliminated within that time, it must be destroyed in the system.

(2) The elimination of alcohol following the taking of a dose of alcohol is completed twenty-four hours after the last dose of alcohol has been taken.

(3) The amount eliminated in both breath and urine is a minute fraction only of the amount of alcohol taken.

Now Dr. J. Percy in 1839 published a research on the presence of alcohol in the ventricles of the brain, and, indeed, he concluded "that a kind of affinity existed between the alcohol and the cerebral matter." He further stated that he was able to procure a much larger proportion of alcohol from the brain than from a greater quantity of blood than could possibly be present within the cranium of the animal upon which he operated.

Dr. Marcet, in a paper read before the British Association in 1859, detailed physiological experiments which he considered to substantiate the conclusions of Percy, inasmuch as they demonstrated that the alcohol acted by means of absorption on the nervous centres.

Lallemand, Perrin, and Duroy had moreover succeeded previously in extracting alcohol from brain-matter in cases of alcoholic poisoning. But all these researches leave us entirely in the dark as regards the true action, if any there be, of alcohol on cerebral matters. And no method of investigation was possible until the chemical constitution of the brain was within our knowledge.

Thudichum's recent researches in this direction, together with some more recent and published investigations by Thudichum and the author, have placed within reach new methods of inquiry regarding the action of alcohol on the brain. In my research I have attempted this inquiry, by maintaining the brains of oxen at the temperature of the blood in water or in water containing known amounts of alcohol. The extracts thus obtained have been studied in various ways and submitted to quantitative analysis, while the influences exerted by the various fluids on the brains have been likewise studied. These influences extend in certain cases to hardening, and to an alteration in the specific gravity of the brain-matter.

Here I shall simply state in the fewest words my results and the conclusions to which they lead.

Water itself has a strong action upon brain-matter (after death), for it is capable of dissolving certain principles from the brain. These principles include cerebrine ($C_{71}H_{66}N_2O_4$), myeline ($C_{44}H_{93}NPO_9$), and apparently a new phosphorized principle insoluble in strong alcohol, together with that class of substances generally termed extractives. At the same time the brain swells and attains a smaller specific gravity: thus in one case from 1036 it became 1007. It is notable that water, however, dissolves no kephaline ($C_{42}H_{79}NPO_{13}$) from the brain.

Alcohol seems to have no more chemical effect on the brain than water itself, so long as its proportion to the total volume of fluid does not exceed a given extent. The limit would appear to exist somewhere near a fluid containing 35 % alcohol. But if the percentage of alcohol exceeds this amount, then not only a larger quantity of matter is dissolved from the brain, but that matter includes kephaline ($C_{42}H_{79}NPO_{13}$). Such alcoholic solutions also decrease to about the same extent as water the specific gravity of brain-substance, but not from the same cause; that is to say, not merely by the loss of substance and swelling, but by the fixation of water. Many difficulties surround the attempt to follow these ideas into life, and to comprehend in what way each or all these modes of action of water and alcohol on the brain may be influenced by the other matters present in blood. From Thudichum's researches it follows that the brain must be subject to every influence affecting the blood; and it is probable, on consideration, that what is written above regarding the action of water on the brain is likewise true of an extraordinary watery serum in life. But if the serum be rich in salts, those salts, by a power of combination which they have for the cerebral principles, would preserve the integrity of the latter. On the other hand it is difficult to see how any of the matters known to exist in the blood could prevent alcohol, if it were present in sufficient amount, either from hardening the brain (as it does after death) or from dissolving traces of the principles to be henceforth carried away in the circulation. That is to say, should physiological research confirm the stated fact that the brain in life absorbs alcohol and retains it, it would almost follow of necessity that the alcohol would act as I have indicated and produce disease, perhaps "delirium tremens."

On the Poisonous Activity of Vanadium in Ortho-, Meta-, and Pyrovanadic Acids. *By* LEOPOLD LARMUTH.

The author concludes from certain experiments detailed that the toxic intensity of orthovanadate of sodium is much less than that of the pyro- and metavanadates of the same base, but that the fundamental mode of action is the same in each.

On the Action and Sounds of the Heart. *By* DR PATON.

Note on the Physiological Action of Vanadium. *By* JOHN PRIESTLEY.

The author described the methods of experiment and observation followed out in a research into the physiological action of vanadium, and concluded by stating the general results arrived at, viz.:—

1. That vanadium is a poisonous substance.
2. That the symptoms of poisoning are, in general, similar whatever the method of the introduction of the salt into the animal system.
3. That the symptoms of poisoning which appeared in one or other of the various classes of animals above mentioned are:—paralysis of motion; convulsions, local or general; rapidly supervening drowsiness or indifference to external circumstances; congestion of alimentary mucous membranes; discharge of sanguinolent fluid fæces; presence of glairy, fluid mucus in the intestines after death; certain changes in respiration, and, coincidently, a fall in temperature; drowsiness and feebleness of pulse. In addition, the heart was always irritable after death, consciousness and sensibility to pain seemed unimpaired, and no diminution could be detected in the powers of muscle and nerve to respond to stimulation.
4. That the lethal dose for rabbits lies between 9·18 and 14·00 milligr. of V_2O_5 per kilogr. of rabbit.

5. That the special action of vanadium on the function of respiration is to cause
(a) A stimulation, followed by
(b) A depression of respiration, the latter being not continuous, but intermittent.

Both effects are considered to be due to an action of the poison upon the respiratory nervous centre.

6. That the special action of vanadium on the function of circulation is to cause
(a) A diminution of blood-pressure, which is not continuous, but intermits during the operation of the poison;
(b) A disappearance of respiration-curves;
(c) A diminution and irregularity of pulse, which is also intermittent.

The results are considered to be due to an action of the poison on the vaso-motor centre and on the intracardiac nervous mechanism.

7. That, although muscles and nerve-trunks speedily die when immersed in even dilute solutions of a sodium salt of vanadium, yet vanadium is not rightly to be called a muscle- and nerve-poison, since frogs which have been poisoned by subcutaneous injection of vanadium still possess nerves and muscles which, in irritability or in power of doing work, are quite normal. Nevertheless vanadium attacks the nervous *centres* of the spinal cord and medulla oblongata.

Observations on the Physiological Action of Chromium.

By JOHN PRIESTLEY.

The author experimented with guinea-pigs, rabbits, and frogs, injecting solutions of neutral chromate of sodium (Na_2CrO_4) beneath the skin or into the veins. He concludes—

1. That ·1 to ·3 grm CrO_3, in the form of the above-named salt, is a powerful poison for rabbits and guinea-pigs.

2. That death is preceded by spasms and violent retching, which commence a few minutes after injection of the poison. Spasms are succeeded by paralysis of motion and, in frogs, abolition of reflex action.

3. That the blood-pressure first rises and then falls, the fall continuing until death. Further, that after the fall has become marked the pulse suddenly becomes abnormal, stopping for the space of a beat or two at irregular intervals, which are occasionally of considerable length, the pulse becoming regular again during the intervals. The author believes that this irregularity of pulse is due to an action on the vagus nervous centre.

4. That the alimentary mucous membranes are the seat of extensive congestion and ecchymoses.

5. That the kidneys become congested.

6. That muscles and nerve trunks and extremities remain sensibly normal.

The Termination of the Nerves in the Vestibule and Semicircular Canals of Mammals.

By URBAN PRITCHARD, *M.D., F.R.C.S., Aural Surgeon to King's College Hospital, Lecturer on Animal Physiology at King's College.*

The author gave the results of his investigations into the structure of the nerve epithelium, as it is called, which contains the terminal distribution of the acoustic nerve.

The membranous labyrinth is composed of three layers—externally some loose connective tissue, then a distinct layer of dense connective tissue (the tunica propria), and lying on this a single layer of tessellated epithelium. At the acoustic spots, where the nerve is distributed, this membrane is firmly adherent to the osseous wall, and the epithelial layer becomes transformed into nerve epithelium.

In the saccule and utricle these spots are termed the maculæ acusticæ, and in the three ampullæ the cristæ acusticæ, the latter being raised into a kind of ridge.

The nerve epithelium.—Max Schultze described this structure as consisting of three elements—a deep layer of nuclei, a superficial layer of cylindrical cells, and between them numerous filiform cells.

Odenius and Kolliker's researches confirmed these observations, but Hasse gives a totally different account of the structure. He describes it as consisting of alternating elongated cells, the one bearing the cilium, the other isolating the ciliated cells, and resting with a broad base on the membrana propria.

Rudinger somewhat reverses the description of Hasse, and states that the isolating cells are triangular, with their bases turned upwards so as to form the free border of the epithelial mass, and doubts the existence of the deep layer of nuclei.

Ebner believes the essential elements to consist of two forms—a superficial layer of cylindrical ciliated cells rounded off below, and a deep multiple layer of filiform cells with their filaments passing up between the cylindrical cells.

Lastly, Paul Meyer describes it as made of two parts—a deep layer of nuclei, and a superficial one of cylindrical ciliated cells tapering off below.

The author's observations have led him to conclusions which, although they are essentially different from those of the authors just alluded to, yet appear to him to reconcile to a great degree their various conflicting descriptions.

The appearance of this structure differs according to the position in the macula of the portion examined.

A typical portion, such as may be seen midway between the centre and circumference of the spot, consists of a layer of alternating elongated cells, bordered above by a distinct cuticular membrane, and connected below with those nuclei which form the deep layer described by most authors. So that the cellular elements may be said to consist of two alternating forms of elongated cells each having an upper and a lower nucleus. The author calls the first the thorn-cells on account of the shape of their cilium, and the second the bristle-cells for a similar reason.

The thorn cells have a fusiform body containing an oval nucleus; from this body passes upwards through the cuticular membrane a tapering cilium or thorn; the lower extremity is prolonged downwards, and again expands to enclose its second nucleus.

The bristle cells have a triangular body containing an oval nucleus; the base of this is intimately connected with the cuticular membrane, and from this base passes upwards a narrow bristle-like cilium ; the apex of this triangular body is prolonged downwards and has a second nucleus like its fellow thorn-cell.

The cuticular membrane is a very thick, well-marked membrane, holding the cellular elements in their place, and perforated for the passage of the cilia. This membrane is analogous to the membrana reticularis of the organ of Corti, and the author therefore proposes to call it by the same name.

Modifications of the nerve epithelium.—As there is a general increase in thickness of the macula from circumference to centre, so the cells and their various parts elongate , the cilia, which are short and stumpy at the edge, become very much longer and comparatively finer at the centre of the acoustic spot. At the circumference the cells pass by insensible gradations into the columnar epithelial cells which surround the whole macula. Towards the centre the upper nucleus and surrounding protoplasm of the bristle cells gradually diminish and then are lost altogether, this part of the cell being represented by a trabecula from the membrana reticularis. The bristle-like cilium remains after the upper protoplasmic mass has disappeared, but eventually this also is lost.

The termination of the nerves in the macula.—The nerve-fibres arriving at the membrana propria lose their white substance, and enter the nerve epithelium without it. After passing this point there is considerable difficulty in tracing the nerve-filaments , but there is no doubt that they form a plexus around the deeper layer of nuclear bodies, and that some of the filaments may be traced directly or indirectly into the ciliated cells.

The otolith mass.—Covering the acoustic spot is a soft mass into which the cilia project to a certain distance , this is evidently of a cuticular nature, and is analogous to the membrana tectoria of the cochlea. The otoliths are fixed by this mass, being chiefly contained in its outer portion.

On a Microscope adapted for showing the Circulation in the Human Subject.
By Dr URBAN PRITCHARD.

Physiology of the Nervous System of Medusæ.
By GEORGE J. ROMANES, M.A., F.L.S., &c.

Fundamental Observations.—The author has succeeded in demonstrating the presence of a nervous system in Medusæ, the ganglionic element of which appears to be localized exclusively in the margin of the swimming-bell. For he found that on excising the entire margin of the bell in any species of naked-eyed Medusæ the swimming motions of the bell instantly ceased and were never again resumed, while the severed margin continued its rhythmical contractions for days. With the covered-eyed Medusæ the case is not quite so definite; for although the paralysis of the bell, which is here likewise produced by the operation just described, is usually complete for a time, it is not always permanent, but, after periods varying from a few seconds to half an hour or more, occasional contractions begin to manifest themselves. Moreover, in the case of the covered-eyed Medusæ, the author found that excision of the lithocysts alone was attended with the same degree of paralyzing effect on the bell as was excision of the entire margin, whereas in the case of the naked-eyed Medusæ such was not the case. Histological observations revealed the presence of ganglion-cells and nerve fibres in the lithocysts.

Natural Rhythm.—As regards the natural rhythm of the Medusæ, it was observed that its rate has a tendency to bear an inverse proportion to the size of the individual, but that on submitting an individual to artificial segmentation, the rate of the rhythm exhibited by the various segments showed a tendency, other things equal, to vary directly as the size of the segment.

When forms of mutilation were practised in which the margin of the swimming-bell was left intact, it was observed that after a temporary acceleration the rate of the rhythm progressively declined, and became stationary at a rate that was slower the greater the amount of tissue that had been removed. From these experiments the author is inclined to infer that the apparently automatic action on the part of the marginal ganglia is really of the nature of a reflex—a constant stimulation being presumably supplied by those other parts of the organism the removal of which was attended with a retardation of the rhythm.

The rate of the rhythm is increased by elevations of temperature as far as 60° F., but in still warmer water (70°–80°) the rate, after having been temporarily quickened, becomes permanently slowed. Diminution of temperature likewise produces a retarding effect on the rhythm, and eventually (20°) altogether stops it.

Some specimens of *Aurelia aurita* were frozen solid, so that all their gelatinous tissues were pierced through in every direction by an innumerable multitude of ice crystals, which had been formed by the freezing, *in situ*, of the sea-water which enters so largely into the composition of these tissues. Yet, on being thawed out, the animals recovered, although their original rate of rhythm did not fully return. Their tissues then presented a ragged appearance, which was due to the disintegrating effect produced by the formation of the ice crystals.

The rate of the rhythm is accelerated by oxygen and retarded by carbonic acid.

Stimulation.—All the contractile tissues of all the Medusæ are keenly sensitive to all kinds of stimulation. When a swimming bell, for instance, is paralyzed by excision of its margin, it invariably responds to a single stimulus by once performing that movement which it would have performed in response to that stimulus had it still been in an unmutilated state. To mechanical stimulation the sensitiveness of the paralyzed bells is wonderfully great—a drop of sea-water let fall from an inch in height upon the contractile tissue being sufficient, in some species, to elicit a responsive contraction. In their responses to all kinds of chemical stimuli, the excitable tissues of the Medusæ conform in every respect to the rules which are followed by the nervo-muscular tissues of higher animals. Similarly with thermal and electrical stimulation. Light also acts as a powerful and unfailing stimulus in the cases of some of the naked-eyed Medusæ. *Sarsia*, for instance, almost invariably responds to a single flash by giving one or more contractions. On removing the margin such responses cease on the part of the bell, although they continue on the part of the severed margin. But on removing the so called "eye specks" from the margin such responses cease; and that these "eye-specks" are true visual organs is further proved by the fact that, while unmutilated *Sarsiæ* will throng into the path of a beam of light, and even follow the beam wherever it is moved through the water, *Sarsiæ* with their "eye specks" removed will no longer do so. Any one of the luminous rays of the spectrum acts as a stimulus, but not so the rays which lie on either side of the luminous spectrum.

The period of latent stimulation was determined in the case of *Aurelia aurita* by employing the induction shock. It was found to vary greatly, according to the temperature at which the tissue was kept. Thus, while in water at 50° it was ½ sec., in water at 70° it was ⅓ sec. It was also found to vary greatly under the influence of so-called summation of stimuli. Thus, while in water at 45° the latent period was ⅝ sec. in the case of the first of a series of stimuli supplied in regular succession at two seconds interval, it was only ⅜ sec. in the case of the tenth stimulus of the series. In every such series of stimuli supplied at short intervals the latent period becomes progressively less and less until it attains its *minimum*, while the strength of the contraction becomes progressively greater and greater until it attains its *maximum*; the intensity of the stimulation, of course, remaining constant throughout the series. If more than one minute is allowed to elapse between any two successive stimuli of a series, this beneficial or arousing effect of summation no longer asserts itself; the tissue has, as it were, forgotten the occurrence of the previous stimuli. That the arousing effect in question is due to the occurrence of the successive *stimulation* and not to the occurrence of the successive *contraction* appears to be indicated by the fact that if induction shocks be employed which are of less than minimal intensity at the commencement of a series, they first become of minimal and eventually, at the end of a series, of more than minimal intensity. Now, as in this case no contraction occurs in response to the first three or four stimuli, it is evident that the summating influence must have reference to the process of stimulation as distinguished from that of contraction. Nevertheless, that the summating effect is a general one pervading the whole extent of the responding tissue, and not confined to the area occupied by the electrodes, is proved by the fact that if, during the administration of a series of stimuli, the electrodes be suddenly shifted to another part of the excitable tissue (perhaps eight or nine inches from their previous seat), the summating effect is resumed from the point at which it was left by the previous stimulus. The author further proved by various experiments that during the *natural* swimming motions of the Medusæ every contraction exerts a beneficial influence on its successor, which resembles both in kind and degree that which is exerted by a contraction due to an artificial stimulus.

Artificial Rhythm.—When the paralyzed disk of *Aurelia aurita* is submitted to strong faradaic stimulation, it goes into a tolerably well-pronounced tetanus. If the strength of the current be now diminished, the tetanus assumes a wild and tumultuous character, somewhat resembling that of a heart under similar circumstances. If the strength of the current be again progressively diminished the character of the tetanus becomes progressively less and less tumultuous, until at last it ceases to be tetanus and passes into rhythm. This artificial rhythm is quite as regular and quite as sustained as is the natural rhythm of the animal. Its rate varies in different specimens, but usually corresponds with that of rapid swimming. Progressively diminishing the strength of the faradaic stimulation has the effect of progressively decreasing the rate of the rhythm down to the point at which all response ceases; but between the slowest rhythm obtainable by minimal stimulation and the most rapid rhythm obtainable before the appearance of tetanus there are numerous degrees of rate to be observed. The artificial rhythm may be obtained with a portion of any size of irritable tissue, and whether a small or a large piece of the latter be included between the electrodes. The persistency of any given rate of rhythm under the same strength of current is wonderfully great, for it generally requires more than an hour of continuous faradization before the rhythm begins to become irregular, owing to incipient exhaustion. At first only one systole is omitted at long intervals, but afterwards these omissions become frequent and all the contractions irregular. Finally the contractions altogether cease, but a rest of half an hour or an hour restores the irritability.

The hypothesis by which the author seeks to explain this artificial rhythm (a rhythm which, in most cases, is quite as regular as the beating of a heart) is as follows:—

Every time the tissue contracts it must, as a consequence, suffer a certain degree of exhaustion, and therefore must become slightly less sensitive to stimulation than it was before. After a time, however, the exhaustion will pass away, and the original degree of sensitiveness will thereupon return. Now the intensity of the faradaic stimulation, which is alone capable of producing rhythmic response, is either minimal, or but slightly more than minimal, in relation to the sensitiveness of the tissue when fresh. Consequently, when the degree of this sensitiveness is somewhat lowered by temporary exhaustion, the intensity of the stimulation becomes somewhat less than minimal in relation to this lower degree of sensitiveness. The tissue therefore fails to perceive the presence of the stimulus, and consequently fails to respond. But so soon as the exhaustion is completely recovered from, so soon will the tissue *again* perceive the presence of the stimulation. It will therefore again respond, again become temporarily exhausted, again fail to perceive the presence of the stimulation, and therefore again become temporarily quiescent. Now it is obvious that if this process occurs once, it may occur an indefinite number of times; and as the conditions of nutrition, as well as those of stimulation, remain constant, it is manifest that the responses may thus become periodic.

In order to test this hypothesis the author made the following experiments. Having first noted the rate of the rhythm under faradaic stimulation of minimal intensity, without shifting the electrodes or altering the strength of the current, he discarded the faradaic stimulation, and substituted for it single induction-shocks thrown in with a key. He found that the maximum number of these single shocks which he could thus throw in in a given time, *so as to procure a response to every shock*, corresponded exactly with the number of contractions which the tissue had previously given during a similar interval of time when under the influence of the faradaic current of similar intensity. For instance, to take a specific case, it was found that under the faradaic current the rate of the rhythm was one in two seconds. By now throwing in single shocks of the same intensity, it was found that the quickest rate at which these could be thrown in, so as to procure a response to every shock, was one in two seconds. If thrown in at a slightly quicker rate, every now and then, at regular intervals, one of the shocks would fail to elicit a response. The length of these intervals, of course, depended on the rate at which the successive shocks were thrown in; so that, for instance, if they were thrown in at the rate of one a second, the tissue would only, but always, respond to every alternate shock.

The following, and somewhat similar, experiment is still more conclusive. As already stated, the rate of the artificial rhythm under faradaic stimulation varies with the strength of the faradaic current. Now, by choosing at random any strength of faradaic stimulation between the limits where rhythmic response occurred, and by noting the rate of the rhythm under that strength, the author was generally able to *predict* the precise number of single induction-shocks he could afterwards afford to throw in with the same strength of current, so as to procure a response to every shock—this number, of course, corresponding exactly with the rate of the rhythm previously manifested under the faradaic stimulation.

Other experiments, which do not admit of being briefly detailed, have likewise confirmed the above hypothesis. Upon this hypothesis, therefore, the author has constructed a theory concerning the rhythmic action of organic tissues in general. The details of this theory cannot be rendered in the present abstract; but in its main outlines it is very simple, viz. that all such rhythmic action is due to the alternate process of exhaustion and recovery of contractile tissues, which has just been explained. Therefore the particular case of rhythmic action of ganglionated tissues is supposed by this theory to be due, not to any special resistance mechanism on the part of the ganglionic tissues, but to the primary qualities of the contractile tissues. In other words, the function of the ganglia is supposed to be merely that of supplying a constant *stimulation*—the *rhythm* being supposed due to the same causes as is the artificial rhythm of *Aurelia aurita* From this it will be seen that the essential point of difference between the current theory of rhythm as due to ganglia and the theory now proposed consists in this—that whereas both theories suppose the *accumulation* of energy by ganglia to be a continuous process, the resistance theory supposes the *discharge* of this accumulated energy to be intermittent, while the exhaustion theory supposes it to be continuous According to the former theory, therefore, the rhythm results because the stimulation is periodic, according to the latter theory, the rhythm results because the alternate process of exhaustion and recovery, or the fall and rise of excitability, is periodic

Without waiting to discuss the *a priori* merits of these rival theories, the author proceeded at once to mention some further experiments which were designed to test the new theory, and which have so far confirmed it as to show the causes which modify the natural rhythm of *Aurelia* likewise modify, in the same ways and degrees, the artificial rhythm

(*a*) Other modes of constant stimulation, besides that supplied by faradaic electricity, likewise cause rhythmic action on the part of the deganglionated tissues of Medusæ For instance, the voltaic current causes this action*, and dilute chemical stimuli tend to produce the same effect

(*b*) With each increment of temperature the rate of the artificial rhythm increases suddenly, just as it does in the case of the natural rhythm Moreover, there seems to be a sort of rough correspondence between the amount of influence that any given degree of temperature exerts on the rate of the natural and of the artificial rhythm respectively Further, it will be remembered that in warm water the natural rhythm, besides being quicker, is not so regular as it is in cold water thus also it is with the artificial rhythm Lastly, water below 20° or above 85° suspends the natural rhythm, and the artificial rhythm is suspended at about the same degrees.

(*c*) Carbonic acid retards and eventually suspends the artificial rhythm, in just the same way as this gas acts on the natural rhythm

(*d*) When the marginal ganglia of *Sarsia* are removed, the manubrium shortly afterwards relaxes to five or six times its normal length. There can be no doubt that this effect is due to the muscular fibres of the manubrium having been previously kept in a state of tonic contraction by means of a continuous ganglionic discharge from the margin Now physiologists are unanimous in regarding muscular tonus as a kind of gentle tetanus due to a persistent ganglionic stimulation, and against this opinion nothing can be said But, in accordance with the accepted theory of ganglionic action, physiologists further suppose that the only reason why some muscles are thrown into a state of tonus by ganglionic stimulation, while other muscles are thrown into a state of rhythmic action by the same means, is because the *resistance* to the passage of the stimulation from the ganglion to the muscle is less in the former than in the latter case On the other hand, the new theory of ganglionic action explains the difference by supposing a different degree of *irritability* on the part of the muscles in the two cases, for it will be remembered that in the author's experiments on paralyzed *Aurelia*, if the continuous stimulation were of somewhat more than minimal intensity, tetanus was the result, while if such stimulation were but of minimal intensity, the result was rhythmic action Now the author finds in the case of *Sarsia* that the muscular tissue of the manubrium *is* more excitable than the muscular tissue of the bell; so that, for this and other reasons, the facts here accord more closely with the exhaustion than with the resistance theory of ganglionic action

Reflex Action—The occurrence of reflex action in the Medusæ is of a very marked character. For instance, if the manubrium be irritated, the swimming-organ responds to the irritation by giving one or more contractions, but if the marginal ganglia be now removed, the swimming-organ no longer responds even to the most violent irritation Again, in *Aurelia*, if only one lithocyst be left *in situ*, and if, during a pause in the activity of the latter, any part of the irritable surface of the swimming-organ be very gently irritated, the resulting contractile wave does not start from the immediate seat of irritation, but from the ganglion which still remains *in situ*.

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* Thus far the results are strikingly similar to those obtained by Dr Forster in the case of the heart-apex.

But this allusion to a "contractile wave" renders it necessary to state that all the contractile motions of the Medusæ (whether due to ganglionic or to artificial stimulation) may be seen to be of the nature of contractile waves which spread from the point of stimulation as from a centre. The rate at which they travel varies greatly in different species, and in the same species under different conditions of temperature &c. The author has made an elaborate series of experiments by section, with the view of ascertaining whether these contractile waves are merely muscle-waves or depend for their passage upon the presence of rudimentary nerves. He finds that the tissue will endure almost any severity of overlapping sections without suffering loss of its physiological continuity—the contractile waves still continuing to zigzag back and fore among the overlapping cuts. Similarly with another form of section which consists in carrying a cut round and round the swimming disk in the form of a spiral, the Medusæ being thus converted into the form of a ribbon. In such a form of section the author has repeatedly seen contractile waves passing freely from end to end of a ribbon shaped strip of tissue measuring only an inch across and more than a yard in length. He was therefore at first inclined to regard these contractile waves as merely muscle-waves. Nevertheless there is likewise an important body of evidence to be adduced in favour of a nervous plexus. In particular, if the spiral mode of section be carried on sufficiently far, a point is, sooner or later, sure to come at which the contractile waves cease to pass forward: they become blocked at that point, *and this always with great suddenness*. Moreover, the point at which such blocking of the waves takes place is extremely variable in different individuals of the same species. Lastly, the fact that reflex action has been proved to occur, shows that these excitable tissues are pervaded by tracts which present the distinguishing function of nerve, viz. the conveying of impressions to a distance. And it is of the first importance to observe that this function is quite as difficult to destroy by the introduction of overlapping or of spiral cuts as is the function on which the passage of contractile waves depends. In other words, reflex action continues to take place through forms of section as severe as those through which contractile waves continue to pass. And this fact the author considers the most important that has as yet been brought to light in the whole range of invertebrate physiology; for he regards it as evidence that in these primitive nervo-muscular tissues the conductile or nervous element becomes differentiated from the contractile or muscular element in such a way that vicarious action is permitted to take place to any extent among the incipient conductile elements. And in striking confirmation of this view another series of observations may here be mentioned.

Tiaropsis indicans is a bowl-shaped species of naked-eyed Medusæ, to which the author has assigned this name in reference to a highly interesting function that is manifested by its manubrium. This function consists in the organ localizing, with the utmost precision, any point of irritation which is situated in the bell. For instance, if any point in the irritable surface of the bell be pricked with a needle, the manubrium moves over towards that point and applies its tapered extremity to the exact spot where the prick has been inflicted. But now, this unerring precision with which the manubrium indicates a seat of irritation in the bell may be completely destroyed by introducing a short cut between the base of the manubrium and the seat of irritation in the bell. The afferent connexions, therefore, on which this localizing function depends are thus shown to be exclusively, or almost exclusively, radial. But although under these conditions the manubrium is no longer able to *localize* the seat of irritation, it nevertheless continues to perceive, so to speak, that irritation is being applied *somewhere*; for every time the irritation is applied the manubrium actively dodges about from one part of the bell to another, applying its extremity now at this place and now at that one, as if seeking in vain for the offending body. Now this fact shows that the stimulus, on reaching the point at which the afferent tract is severed, *escapes* from the severed to the unsevered tracts through the *vicarious* action of the latter.

There is another point of interest connected with this apparently reflex action

When the author removed the manubrium at its base, he found that on now irritating any part of its own substance the apex endeavoured to curve down towards the seat of irritation. Similarly, if only a portion of the manubrium were removed, the pointing action of that portion resembled the pointing action of the entire organ, while the stump that remained *in situ* would continue to move over as far as it could towards any point of irritation situated in the bell. Hence there can be no doubt that every part of the manubrium is independently endowed with the capacity of localizing a seat of irritation either in its own substance or in that of the bell. And in this we have a very remarkable fact, for the localizing function which is so very efficiently performed by the manubrium of this Medusa, and which, if any thing resembling it occurred in the higher animals, would certainly have definite ganglionic centres for its structural correlative, is here shared equally by every part of the exceedingly tenuous contractile tissue that forms the outer surface of the organ. We have thus in this case a general diffusion of ganglionic function, which is coextensive with the contractile tissues of the organ.

Poisons.—The author has conducted a number of experiments with reference to the effects of the various nerve- and muscle-poisons on the primitive nervo-muscular tissues. He has tried chloroform, ether, morphia, caffein, nitrate of amyl, alcohol, nicotin, strychnia, veratrium, digitalin, atropin, curare, cyanide of potassium, &c., &c., and he finds that in the main all these poisons exert precisely the same effects on the Medusæ as they do on the higher animals. A vast number of other observations were detailed which do not admit of being briefly abstracted. Those who are interested in the subject are therefore referred to the 'Philosophical Transactions,' where a full account of the research is to be found.

New Researches on the Electrical Phenomena consequent on Irritation of the Leaves of the Fly-trap (Dionæa muscipula). *By* Prof. BURDON SANDERSON, *F.R.S.*

s Apparatus of the Lungs. *By* Dr WILLIAM STIRLING.

An Account of Finger-muscles found in the Greenland Right Whale. *By* Prof. STRUTHERS.

An Account of Dissections of the supposed Rudimentary Hind Limb of the Greenland Right Whale. *By* Prof. STRUTHERS.

On the Structure of the Placenta in relation to the Theory of Evolution. *By* Prof. W. TURNER, *F.R.S.E.*

On the Effects of the Mineral Substances in Drinking-Water on the Health of the Community. *By* J. A. WANKLYN.

ANTHROPOLOGY

[For A Russel Wallaces Address see page 100]

On the Oldest Woman in Scotland *By* General Sir J ALEXANDER

On some Phenomena associated with Abnormal Conditions of Mind
By Prof BARRETT, F R S E

Primitive Agriculture *By* A W BUCKLAND, M A I

Believing the study of Primitive Agriculture to be of great importance in connexion with the migrations and social intercourse of races in the prehistoric times, I have endeavoured to show —

1st The antiquity of the art and its bearing upon civilization, that it could only have originated among people having a settled abode, and therefore was probably first practised in a very imperfect state by the women of tribes left in tents or villages to await the return of hunters—a probability which is strengthened by the fact that women are still the sole agriculturists among many semicivilized races

2nd That although agriculture may have originated in many lands and at different times many peoples yet remain in total ignorance of it, and the agriculture of the lower races consists in the cultivation of indigenous roots and fruits, the cultivation of the cereals being confined to civilized races and to those who have learnt it through contact with them

3rd That the origin and native land of all the cereals remains obscure, although all, excepting maize, are supposed to be indigenous in the eastern hemisphere, whilst maize is affirmed to be of American origin and to have been unknown in the Old World before the time of Columbus This last assertion I have ventured to dispute, from the fact that travellers have found it in cultivation in various parts of Asia and Africa before any intercourse had arisen with white men and because it is described in the 'Newe Herball' published 1578, as *Frumentum Turcicum* or *Asiaticum*

4th That there are traces in America, China, and ancient Egypt of a time, anterior to the cultivation of cereals, when the aborigines of these countries fed, as the Pacific islanders do now, upon fruits and roots, some of them poisonous, but rendered wholesome by pounding, maceration, and desiccation, and that this primitive state in these countries is confirmed by the annals of China, by the testimony of Herodotus, and by American myths

5th That a similarity in the customs, myths, monuments, and religions of China, Egypt, Peru, and Mexico leads to the conclusion that a cognate pre-Aryan race introduced the cultivation of the cereals into all these countries, and with them the worship of the Moon as an agricultural deity

6th That the absence of agricultural implements from prehistoric discoveries proves their extreme simplicity, being probably only a pointed stick, which still forms the sole agricultural implement in many countries, whilst it is not improbable that some of the stone celts were employed as hoes, and that flint flakes inserted in wooden frames served then, as they do now in the East, as harrows and threshing implements, and that furrows and ridges seem everywhere to have been used in the cultivation of grain, whilst corn-hills seem to be confined to America, although used in Africa in the cultivation of mandioca

7th That the traces of primitive agriculture confirm the conclusions of modern ethnologists as to the early condition, gradual development, and extensive migrations of the human race

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On Relation of Gaelic and English. *By* Rev Mr CAMERON

On the Prehistoric Names for Man, Monkey, Lizard, &c.
By Hyde Clarke, *M.A.I.*

The writer first stated that the Australians call the white man Wanda, also a word for spirit, demon, or angel In African languages, Wandum and Wam are names for man · the names for man in African and Central-American languages interchanged with those for monkey, lizard, frog, of these numerous examples were given In Assyrian monkey is "udumu," which Rev W Houghton compares with the Hebrew Adam as related to the anthropoid ape The Aryan Man and Son are found in Africa and the prehistoric world in such relation as all Aryan pre-historic roots are There was no separate creation or development of Aryan roots, though there was a selection, and Sanskrit words may be found among some of the lowest savages in Africa This thing is certain, that the Aryan languages were first those of blacks, as are most of the languages of the world, and the words supposed to represent an Aryan civilization are those of the culture of the earliest blacks and savages So, too, as to primitive mythology, in the facts above stated will perhaps be found the origin of totem worship and of animal ancestors

On Hittite, Khita, Hamath, Canaanite, Lydian, Etruscan, Peruvian, Mexican, &c. *By* Hyde Clarke, *M A I.*

This paper embraces the author's investigations on that family and epoch to which he had given the name of Sumero-Peruvian, but to which the title of Hittite had lately been given Beginning with the Canaanites, the Hittites, &c , he stated his investigations as to the decipherment of the Hittite or Hamath inscriptions and the Canaanite terms in the Bible This part embraced in copious tables the parallelism of Canaanite town names recorded in Scripture with those of Asia Minor, pre-Hellenic Greece, Etruria, Italy, Iberian Spain (not Basque), Babylonia, India, Peru, and Mexico Applying this evidence again to support the linguistic, the community of Etruscan with Lydian and Hittite was affirmed The earliest culture of India was assigned to the same family Adopting the mass of evidence, the languages and culture of the great kingdoms of America were explained as being of a like epoch with the "Hittite," and the phenomena of an arrested culture in America were accounted for Thus while there were points of conformity in culture and mythology, America never shared in the highest stages in the Semitic or Aryan developments Traces of the tradition of the former communication with the New World were illustrated.

On a Sooloo Skull. *By* Prof. Cleland, *F R.S.*

On the Phœnicians. *By* C. O. Groom Napier.

On the Natives of British Guiana. *By* W. Harper.

On the Eastern Picture-writing. *By* J. Park Harrison

On the Rodiyas of Ceylon. *By* Bertram F Hartshorne.

On Horned Men of Akkem, in Africa.
By Captain J. S. Hay *and* Commander Cameron, *C.B.*

On the Laplanders and People of the North of Europe.
By H. v. HUMBOLDT v. D. HORCK.

The Classification of Arrow-heads. *By* W. J. KNOWLES.

The author objected to the present classification. One author applies the term triangular to a slightly indented type of arrow-head, and indented to a more deeply indented type, while another includes under the name triangular both triangular and indented arrow-heads. He also objected to the term leaf-shape, as stemmed and indented arrow-heads often closely resemble leaves. He suggested that "ovate" for broad and short, and "lanceolate" for the narrow and elongated forms, would be more appropriate type names for the so-called leaf-shape. He also objected to arrow-heads with four straight edges but much more elongated at one end than the other being classed as lozenge-shaped. This form has often the edges of the base arched outwards and those of the point inclining inwards. He would include such under the name kite-shape, and apply the term lozenge-shaped only to those arrow-heads which had four edges of equal length. He would apply the term triangular only to arrow-heads having three straight edges, and indented to those which were indented at the base, whether much or little. Those which had a central tang or stem, whether barbed or not, he would, to save confusion, include under the term stemmed. He considers that this arrangement would retain many of the old terms with which we are familiar, and yet considerably improve matters. Our classification would then be stemmed, indented, triangular, ovate, lanceolate, kite-shaped, lozenge-shaped, and if the term leaf-shaped has got too great a hold to be given up he suggests that it could be retained and ovate and lanceolate dropped for the present.

Additional Remarks on the Find of Prehistoric Objects at Portstewart.
By W. J. KNOWLES.

The author referred to the objects (arrow-heads, scrapers, &c.) which he had found in pits among sandhills at Portstewart, at the time he brought the matter before the Belfast meeting in 1874, and stated that the most remarkable find since that time had been about a dozen very small beads of serpentine, concave on one side and convex on the other, which probably formed part of a necklace that had been lost, or which had been placed in an urn at the time of an interment. They were all found within a few yards of the same spot. He also found one of those stones known as *Tilhuggersteens* or oval tool stones, and from being found with the flint implements, he argued that it belonged to the Stone Age. He also found bones and a portion of deer-horn which had been deeply cut, and he endeavoured to show, from experiments made by himself on a common beef-bone with a flint flake, that the cutting had been made by flint tools.

On Bosjes Skulls. *By* DR. KNOX.

On the Origin of Instinct. *By* REV. J. M'CANN, *D.D.*

On the Gaelic Inhabitants of Scotland. *By* HECTOR MACLEAN.

The author gave some of the results of his investigations into the non-Aryan element of the Gaelic tongue, and argued for the existence in Scotland of one or more pre-Keltic races, who were gradually kelticized by the Caledonians and other invaders from the east.

On the Anglicizing and Gaelicizing of Surnames. By HECTOR MACLEAN.

It was shown that the value of surnames as tests of race, or of the proportion of race-elements, in the Scottish Highlands, as well as in Ireland, was much impaired by the frequent adoption, both in the middle ages and in recent times, of translated or of like-sounding surnames reciprocally by the two races in contact with each other in those countries, and numerous examples were given of such changes, *e.g.* MacIan into Johnson.

Explorations in the Islands of the Coral Sea. By KERRY-NICHOLLS.

Natives of New Hebrides, Banks, and Santa-Cruz Islands.

The natives inhabiting these islands owe their origin to the same stock from which the western and southern portion of New Guinea and the islands lying immediately to the southward of that country appear to have been peopled. This stock is evidently Papuan, and has by its numerous and widespreading branches not only extended itself over the islands of the Coral Sea, but as far east as the Fijis, in which latter country, however, the race has evidently received a strong infusion of Malay blood.

It is probable that the islands were inhabited at a very remote period, but at what era population set in, whether at the first instance it was purely accidental and subsequently gradual, or whether originally it was undertaken from design and accelerated at any particular period by political convulsions, cannot at present be determined, as there is no date on which to rely with confidence. But whatever opinion may be formed on the identity of the present race, the striking resemblance in person, feature, language, and customs which prevails throughout justifies the conclusion that the original population issued from the same source, and that the peculiarities and characteristics which distinguish the tribes or communities on different islands have been mainly brought about by long separation, local circumstances, and the intercourse of foreign traders and settlers.

Physically considered these people are a well-built athletic race of savages, who appear to inherit in a very marked degree all the characteristics of the Papuan race. The men average about 5 feet 6 inches in height, are erect in figure, with broad chests and massive limbs, which in many instances display great muscular development. The colour of the skin is usually of a dark reddish brown, but sometimes it is quite black, and is often covered with short curly hair, especially about the breast, back, and shoulders. They have large well-formed heads, the facial angle is about 40°, while the cranium in the majority of instances betokens a fair degree of mental development. The features are usually regular in form, the forehead high and massive, with a considerable prominency in the region of the frontal bone; the nose is mostly flat, but in some instances aquiline, the nostrils wide, the mouth large and firm, the lips well cut and slightly full; the teeth square, strongly set and very white and even, while the eye, large, of a dark brown colour and shaded by long lashes, is not too deeply set and is quick and penetrating in its glance.

The hair, which forms one of the most remarkable features of this race, is distributed thickly over the head in the form of small spiral curls, and when allowed to grow in its natural way has a woolly appearance, and resembles at first glance that of the African negro; but it is in reality much finer and softer. The beard, which is of the same crisp curly nature as the hair, is worn short. In the northern islands the men go completely naked, but in the southern islands, where the climate is slightly cooler, they affect a scant covering about the loins. They are fond of decorating the head with flowers and feathers and of tattooing the face with red and blue pigments, which imparts to them a savage and ferocious look. The form of tattooing, however, varies much upon different islands, and seems to serve as a distinctive mark among the various tribes inhabiting them. On the island of Tana the natives tattoo each cheek with big patches of red pigment, and wear blue streaks under the eyes and across the forehead. On the other islands various forms of tattooing prevail, but in Banks' group, where there appears to have been at some time or other an admixture of Malay blood, a totally different kind of tattooing obtains from that of the islands of the southward Here the bodies, especially of the women, are often completely covered with tattoo marks representing lace-work of the most artistic design This style of tattooing is often extended so as to cover the body entirely from the feet, over the face and even to the very roots of the hair This mode of decoration is performed by puncturing the skin with a sharp bamboo instrument something like a comb and then rubbing in a blue liquid dye obtained from the juice of a plant common upon the islands All the islanders are very fond of showy ornaments in the shape of necklaces made of beads and coloured shells They have the septum of the nose pierced, as likewise the lobes of the ears, into which are thrust all kinds of decorations The features of the women are much flatter than those of the men, and they are in stature considerably shorter, there are, however many marked exceptions to this rule Their limbs are round and well turned, but the long pendulous breasts of the married women detract greatly from their otherwise symmetrical proportions Their only dress is a short covering made of the plaited filaments of the plantain-leaf or simply of native grass attached to a cord round the waist but this primitive costume varies greatly on different islands I met with two Albinoes,—one a man, on the island of Esperitu Santo, the other was a woman, whom I fell in with when crossing the island of Vanu Lava In appearance they were both very ugly, the latter was exceedingly stout, and her skin of a pinkish-white colour was speckled all over with dark red spots about the size of peas, while she had pink eyes, very weak and inflamed and light sandy coloured hair

All things considered, the physical condition of the islanders does not appear to manifest any sign of degeneration As a rule the natives inhabiting the various islands appear to be healthy and vigorous The prevailing diseases are dysentery, fever, and ague, chronic rheumatism, scorbutic affections, ophthalmia and elephantiasis They seem to have little or no notion of medical skill, but place great faith in charms and incantations for the cure of the diseases from which they suffer

In tracing the distribution of the several races inhabiting the Pacific Islands a marked difference is observable in the construction and decoration of the various implements of war and the canoes employed by the natives on various islands The war implements of the Malays are remarkable for neatness of construction, skilful carving, and various other artistic decorations, while their canoes are lightly built, tastefully painted, and inlaid with pearl shell about the prow, which is usually curiously carved These canoes are often capable of carrying from fifty to sixty men On the other hand, among the Papuans their war implements are mostly very rude in construction, and there is far less of the decorative art displayed in their manufacture Their canoes likewise, although large, can lay no claim to artistic design, while on some islands they assume the most primitive form, being made simply from huge logs hollowed out by fire But even the Papuans themselves show a variety of design in the construction of their weapons, and which varies upon different islands On the island of Tana the war club a favourite weapon, is very heavy, and requires to be wielded with both hands Many of these clubs are highly polished, but the carving about them is of the simplest design On the island of Erromango the spears are made entirely of wood, the points being neatly carved and barbed The natives of this island also use a weapon of oval shape, in form not unlike the paddle of a canoe, the edges of which are hardened by fire and made very sharp On the island of Esperitu Santo the spears are usually of great length, often as much as from 10 to 12 feet, the heads of them are made of human thigh-bone, sharply pointed and barbed while all are poisoned The chiefs of this island, when in full war-costume, wear human jawbones around the left wrist, and carry one of these long spears with three prongs to it and sharp needle-like points of bone coming a considerable distance down the shaft These spears are highly prized as emblems of chieftainship, and are handed down as heirlooms from one chief to another The bows are often of great power, and on the Santa-Cruz Islands, where Bishop Patteson and Commodore Goodenough were murdered, they are all from 8 to 10 feet long, the arrows being as much as 4 feet in length. On all the islands the arrows are tipped with human bone, and are carefully barbed and poisoned, a scratch from one of them being sufficient to cause death.

On an Urn from Chudleigh, Devon. *By* W. Pengelly, *F.R.S.*

In February 1876, some workmen, digging a pit in a field on the property of Mr. W. Brodrick, near Chudleigh, in Devonshire, discovered an urn two feet below the surface. The urn was unfortunately broken by the workmen's tools before it was seen; but Mr. Brodrick, who was immediately called, found its base intact and *in situ*, with fragments of bone and bits of charcoal lying on it undisturbed. Efforts were made to preserve the integrity of the bottom, but utterly failed, and the urn is now simply a heap of about 70 small fragments. It is obvious, however, that its base was ellipsoidal, and measured about 7×4.5 inches. Mr. Franks is of opinion that there is no reason to doubt that the urn is Roman, and perhaps made in this country. Mr. Busk and Mr. Flower say there is no suspicion of the bones being human, but that they think them, without doubt, those of goat or sheep, with the possible exception of a fragment of a tibia.

On Relics of Totemism in Scotland in Historic Times. *By* J. S. Phené.

On the Arthurian Apple and the Serpent of the Ancients. *By* J. S. Phené.

On Right-handedness. *By* James Shaw.

On the Mental Progress of Animals during the Human Period.
By James Shaw.

On two Skulls from the Andaman Islands. *By* Dr. Allen Thomson, *F.R.S.*

GEOGRAPHY

Address by F. J. Evans, *C.B., F.R.S., Captain R.N., President of the Section.*

Two events notable in the annals of Geographical Science have to be recorded since the last meeting of the British Association, and these events, as bearing materially on the advancement of our knowledge of geography, are deserving the special commendation of this Section. I refer to the successful issue of Cameron's land journey across the tropical regions of Southern Africa, and to the successful completion of the sea voyage of the 'Challenger'—a voyage which in its scope included the circumnavigation of the globe, the traversing the several oceans between the 50th parallel of North latitude and the antarctic circle, and the exploration throughout, by the medium of the sounding-line and dredge, of the contour-features, the formation, and the animal life of the great oceanic bed.

The general results of the notable African land journey have already, through our parent Society in London, been brought largely under public review, and at our present meeting many details of interest will be placed before you by the intrepid traveller himself The courage, perseverance, and patient attention to the records of this long travel have been dwelt on by our highest geographical authorities, and so far it might appear superfluous to join in praise from this chair, nevertheless it is to that part of the proceedings of Cameron, the unvarying attention and care he bestowed on instrumental observations in order to give those proceedings a secure scientific basis, to which I would direct your attention as being of a high order of merit.

With this example before us, remembering the country and climate in which such unremitting labours were carried out, distinction to the future explorer cannot rest on the mere rendering of estimated topographical details, but can alone be fully merited when those details are verified by instrumental observations of an order sufficient to place numerically before geographers the physical features and characteristics of the explored region

Turning now from the results of the land journey of Cameron to those of the sea voyage of the 'Challenger,' we are again reminded of the value of repeated and methodically arranged instrumental observations in geographical research. With our present knowledge of the sea-board regions of the globe, little remains, except in polar areas, for the navigator to do in the field of discovery, or even of exploration, otherwise than in those details rendered necessary by the requirements of trade or special industries It is to the development of the scientific features of geography that the attention of voyagers requires to be now mainly directed, and in this there is an illimitable field. The great advance in this direction resulting from the two leading events of the past year, to which I have referred, foreshadows the geographical research of the future

Communications of special value from some of those voyagers whose good fortune it was to leave and return to their native land in the ship 'Challenger' will doubtless be made to this and other Sections I trust nevertheless, as one officially interested in the expedition from its inception, and as having in early days been engaged in kindred work, and also, as I hope, without being considered to have trespassed on the scientific territories of these gentlemen (ground indeed so well earned), this meeting will view with indulgence my having selected as the leading theme of my address to it a review of that branch of our science now commonly known as the "Physical Geography of the Sea," combined with such suggestive matter as has presented itself to me whilst engaged in following up the proceedings of this remarkable voyage

It has been well observed that "contact with the ocean has unquestionably exercised a beneficial influence on the cultivation of the intellect and formation of the character of many nations, on the multiplication of those bonds which should unite the whole human race, on the first knowledge of the true form of the earth, and on the pursuit of astronomy and of all the mathematical and physical sciences" The subject is thus not an ignoble one, and, further, it appears to me appropriate, assembled as we are in the commercial metropolis of Scotland, from among whose citizens some of the most valuable scientific investigations bearing on the art of navigation have proceeded.

As a prefatory remark, I would observe that the distinctive appellation "Physical Geography of the Sea" is due to the accomplished geographer Humboldt, it is somewhat indefinite though comprehensive, and implies that branches of science not strictly pertaining to geography as commonly understood are invaded. But this intrusion or overlapping of scientific boundaries is inevitable with the expansion of knowledge; and it is difficult to see how the term can be wisely amended, or how the several included branches of physics can be separated from pure geographical science.

We are indebted in our generation to the genius and untiring energy of Maury, aided originally by the liberal support of his Government, for placing before us, in the twofold interests of science and commerce, an abundant store of observed facts in this field, accompanied too by those broad generalizations which, written with a ready pen and the fervour of an enthusiast gifted with a poetic temperament, have charmed so many readers, and in their practical bearings have undoubtedly advanced the practice of navigation.

In our admiration, however, of modern progress we must not in justice pass by without recognition the labours of earlier workers in the same field. So early as the middle of the seventeenth century we find, in Holland, Barnard Vanerius describing with commendable accuracy the direction of the greater currents of the Atlantic Ocean and their dependence on prevailing winds—the unequal saltness of the sea, the diversity of temperature, as the causes of the direction of the winds—and also speculating on the depths of the sea. Vanerius's geographical writings were highly appreciated by Newton, and editions were prepared at Cambridge under the supervision of that great man in 1672 and 1681.

To Dampier, the seaman, and Halley, the philosopher, we owe graphic descriptions of the trade-winds as derived from personal experience, while their causes were investigated by Hadley, and the conclusion he arrived at, that they were due to the combined effects of the diurnal revolution of the earth on its axis and the unequal distribution of heat over different parts of the earth's surface, in substance still remains unchallenged.

To Rennell we owe a masterly investigation of the currents of the Atlantic Ocean, an investigation which for precision and a thorough conception of the conditions affecting the subject will long serve as a model for imitation. His period covered some thirty or forty years during the end of the last and the beginning of the present century. At that epoch chronometers though very efficient, had scarcely passed the stage of trial, but had nevertheless commended themselves to the first navigators of the day whose aim it was to narrowly watch and test this, to them, marvellous acquisition. Rennell thus commanded nautical observations of a high order of merit, these he individually verified, both for determining the ship's position absolutely and relatively to the course pursued, and our knowledge of surface currents was established on the secure basis of differential results obtained at short intervals such as a day or parts of a day, instead of the previous rude estimation from a ship's reckoning extending over a whole voyage, or its greater part.

At a later date we have, by Redfield, Reed, Thom, and others solidly practical investigations of the gyratory and at the same time bodily progressive movements of those fierce and violent storms which, generated in tropical zones, traverse extensive districts of the ocean, not unfrequently devastating the narrow belt of land comprised in their track, and on the sea baffling all the care and skill of the seaman to preserve his ship scathless, while the clear and elegant exposition by Dove of their law and its application as one common general principle to the ordinary movements of the atmosphere must commend itself as one of the achievements of modern science.

While for the moment in the aerial regions, we must not forget the industry and scientific penetration of the present excellent secretary of the Scottish Meteorological Society. His more recent development of the several areas of barometric pressure, both oceanic and continental, bids fair to amend and enlarge our conceptions of the circulation of both the aerial and liquid coverings of our planet.

Looking then, from our immediate stand-point on the extent of our knowledge (as confirmed by observational facts) of the several branches of physics pertaining to the geography of the sea, just rapidly reviewed, we find that, resulting from the methodical gathering up of "ocean statistics" by our own and other maritime nations, in the manner shadowed forth by Maury and stamped by the Brussels Conference of 1853, we are in possession of a goodly array of broad but nevertheless sound results. The average seasonal limits of the trade-winds and monsoons, with the areas traversed by circular storms, are known, also the general linear direction and varying rates of motion of the several ocean currents and streams, together with the diffused values of air and sea-surface temperatures, the areas of uniform barometric pressure, and the prevalent winds, over the navigable parts of the globe.

Thus far the practical advantages that have accrued to the art of navigation (and so directly aiding commerce) by the gradual diffusion of this knowledge, through the medium of graphical rendering on charts and concise textual descriptions, cannot be overrated; still much is wanting in fulness and precision of detail, especially in those distant but limited regions more recently opened out by expanding trade. Science views, too, with increasing interest these advances in our knowledge of ocean physics, as bearing materially on the grand economy of nature: essays, brilliant and almost exhaustive on some of its subjects, have been given to us by eminent men of our own day; but here one is reminded, by the diversity in the rendering of facts, how much remains to be done in their correlation, and what an extensive and still expanding field is before us.

The dawning efforts of science to pass beyond the immediate practical requirements of the navigator are worthy of note. We find—from an admirable paper on the "Temperatures of the Sea at different Depths," by Mr Prestwich, just published in the Philosophical Transactions—that in the middle of last century the subject of deep-sea temperatures first began to attract attention, and thermometers for the purpose were devised; but it was not till the early part of the present century that the curiosity of seamen appears to have been generally awakened to know more of the ocean than could be gleaned on its surface. John Ross, when in the Arctic seas in 1818, caught glimpses of animal life at the depth of 6000 feet; other navigators succeeded in obtaining the temperature of successive layers of water to depths exceeding 6000 feet; but, so far as I can ascertain, James Ross was, in 1840, the first to record beyond doubt that bottom had been reached, "deeper than did ever plummet sound," at 16,000 feet, westward of the Cape of Good Hope.

The impetus to deep sea exploration, however, was given by the demand for electrical telegraphic communication between countries severed by the ocean or by impracticable land routes; and the past twenty years marks its steady growth. Appliances for reaching the bottom with celerity, for bringing up its water, for bringing up its formation, for registering its thermal condition *in situ*, have steadily improved; and thus the several oceans were examined both over present and prospective telegraph-routes. Science, aroused by the consideration that vast fields for biological research were opening up—as proved by the returns, prolific with living and dead animal matter rendered by the comparatively puny appliances originally used for bringing up the sea bottom—invoked, as beyond the reach of private enterprise, the aid of Government. Wisely, earnestly, and munificently was the appeal responded to; and thus the 'Challenger' expedition has become the culminating effort of our own day.

We have now reached, in all probability, a new starting-point in reference to many of our conceptions of the physics of the globe; and our own special branch may not be the least affected. There is opened up to us, for example, as fair a general knowledge of the depression of the bed of large oceanic areas below the sea-level, as of the elevation of the lands of adjacent continents above that universal zero-line. We learn for the first time by the 'Challenger's' results—ably supplemented as they have recently been by the action of the U S Government in the Pacific, and by an admirable series of soundings made in the exploratory German ship of war 'Gazelle'—that the unbroken range of ocean in the southern hemisphere is much shallower than the northern seas, that it has no features approaching in character those grand abyssal depths of 27,000 and 23,600 feet found respectively in the North Pacific and North Atlantic Oceans, as the greatest reliable depths recorded do not exceed 17 000 or 17 500 feet.

The general surface of the sea-bed presents in general to the eye, when graphically rendered on charts by contour lines of equal soundings, extensive plateaux varied with the gentlest of undulations. There is diversity of feature in the western Pacific Ocean, where, in the large area occupied by the many groups of coral islands, their intervening seas are cut up into deep basins or hollows, some 15 000 some 20 000 feet deep. In the northern oceans one is struck with the fact that the profounder depths in the Pacific occupy a relative place in that ocean with those found in the Atlantic. Both abyssal areas have this too in common: the maximum depths are near the land; the sea-surface temperature has the maximum degree of heat in either ocean; and two of the most remarkable ocean streams (Florida-Gulf and Japan) partially encompass them.

In the Atlantic Ocean, from a high southern latitude a broad channel, with not less than some 12,000 to 15,000 feet, can be traced as extending nearly to the entrance of Davis Strait; a dividing undulating ridge of far less depression, on which stand the islands of Tristan d'Acunha, St. Helena and Ascension, separates this, which may be named the western channel, from a similar one running parallel to the South-African continent, and which extends to the parallel of the British Islands. It is possible that certain tidal and, indeed, climatic conditions peculiar to the shores of the North Atlantic may be traced to this bottom conformation, which carries its deep, canal-like character into Davis Strait, and between Greenland, Iceland, and Spitzbergen, certainly to the 80th parallel.

There is, however, one great feature common to all oceans, and which may have some significance in the consideration of ocean circulation, and as affecting the genesis and translation of the great tidal wave and other tidal phenomena, of which we know so little—namely, that the fringe of the seaboard of the great continents and islands, from the depth of a few hundred feet below the sea-level, is, as a rule, abruptly precipitous to depths of 10,000 and 12,000 feet. This grand escarpment is typically illustrated at the entrance of the British Channel, where the distance between a depth of 600 feet and 12,000 feet is in places only ten miles. Imagination can scarcely realize the stupendous marginal features of this common surface-depression.

Vast in extent as are these depressed regions—for we must recollect that they occupy an area three times as great as the dry land of the globe, and that a temperature just above the freezing-point of Fahrenheit prevails in the dense liquid layers covering them—life is sustained even in the most depressed and coldest parts; while in those areas equivalent in depression below the sea-level to the elevation of European Alpine regions above it animal life abundantly prevails, structural forms complicated in arrangement, elegant in appearance, and often lively in colour clothe extensive districts; other regions apparently form the sepulchral resting-place of organisms which when living existed near the surface, their skeletons, as it has been graphically put, thus "raining down in one continuous shower through the intervening miles of sea water." Geological formations, stamped with the permanency of ages, common to us denizens of the dry land, appear, too, in these regions to be in course of evolution; forces involving the formation of mineral concretions on a grand scale are at work; life is abundant everywhere in the surface and sub-surface waters of the oceans; in fine, life and death, reproduction and decay, are active in whatever depths have been attained.

As a question of surpassing interest in the great scheme of nature, the economy of Ocean Circulation, affecting as it does the climatic conditions of countries, has of late attracted attention. The general facts of this circulation in relation to climate have been thus tersely summarized:—"Cold climates follow polar waters towards the equator; warm climates follow warm equatorial streams towards the poles." We can all appreciate the geniality of our own climate, especially on the western shores of the kingdom, as compared with the Arctic climate of the shores of Labrador, situated on the same parallels of latitude, or indeed with the vigorous winter climate of the adjacent North-American seaboard, even ten degrees further to the south. These, and kindred features in other parts of the globe, have led to the summarized generalization I have just referred to; but the *rationale* of these movements of the waters is by no means assured to us.

That ocean currents were due primarily to the trade and other prevailing winds, was the received opinion from the earliest investigation made by navigators of the constant surface-movement of the sea. Rennell's views are thus clearly stated:—"The winds are to be regarded as the prime movers of the currents of the ocean; and of this agency the *trade-winds* and *monsoons* have by far the greatest share, not only in operating on the *larger half* of the whole extent of the circumambient ocean, but as possessing greater power by their constancy and elevation to generate and perpetuate currents;" . . . "next to these, in degree, are the *most prevalent* winds, such as the westerly winds beyond, or to the north and south of, the region of trade winds."

Maury, so far as I am aware, was the first to record his dissent from these generally received views of surface-currents being due to the impulse of the winds, and assigned to differences of specific gravity, combined with the earth's rotation on its axis, the movement of the Gulf-stream and other well-defined ocean currents.

A writer of the present time, gifted with high inductive reasoning powers, and with observed facts before him in wide extension of those investigated by Rennell, regards the various ocean currents as members of one grand system of circulation, not produced by the trade-winds alone, nor by the prevailing winds proper alone, but by the continued action of all the prevailing winds of the globe regarded as one system of circulation; and, without exception, he finds the direction of the main currents of the globe to agree exactly with the direction of the prevailing winds.

Another writer of the present day, distinguished for intellectual power, and who personally has devoted much time in the acquisition of exact physical facts bearing on the question both in the ocean near our own shores and in the Mediterranean sea, without denying the agency of the winds so far as surface-drifts are concerned, considers that general Ocean Circulation is dependent on thermal agency alone, resulting in the movement of a deep stratum of polar waters to the equator, and the movement of an upper stratum from the equator towards the poles, the disturbance of hydrostatic equilibrium being produced by the increase of density occasioned by polar cold and the reduction of density occasioned by equatorial heat—and that polar cold rather than equatorial heat is the *primum mobile* of the circulation. Analogous views had also been entertained by Continental physicists from sea-temperature results obtained in Russian and French voyages of research in the early part of this century.

We have here presented to us two distinct conceptions of Ocean Circulation—the one to a great extent confined to the surface and horizontal in its movements, the other vertical, extending from the ocean surface to its bed, and involving as a consequence "that every drop of water will thus [except in confined seas] be brought up from its greatest depths to the surface."

With these several hypotheses before us, it may be fairly considered that the problem of "Ocean Circulation" is still unsolved. Possibly, too, the real solution *may require the consideration of physical causes* beyond those which have been hitherto accepted. In attempting the solution, it appears to me impossible to deny that the agency of the winds is most active in bringing about great movements of the surface waters, the effects of the opposite monsoons in the India and China seas furnishing corroborative proof. Again, the remarkable thermal condition of the lower stratum of the water in enclosed seas, as the Mediterranean, and in those basin-like areas of the Western Pacific cut off by encircling submarine ridges from the sources of polar supplies, combined with the equally remarkable condition of cold water from a polar source flowing side by side or interlacing with warm water from equatorial regions, as in the action of the Labrador and Gulf-streams, points to the hypothesis of a vertical circulation as also commanding respect.

The time may be considered, however, to have now arrived for gathering up the many threads of information at our disposal, and by fresh combinations to enlarge at least our conceptions, even if we fail in satisfying all the conditions of solution. To this task I will briefly address myself.

A grand feature in terrestrial physics, and one which I apprehend bears directly on the subject before us, is that producing ice movement in the Antarctic seas. We know from the experience gained in ships (which, to shorten the passages to and from this country, Australia, and New Zealand, have followed the great-circle route, and thus attained high southern latitudes) that vast tracts of ice from time to time become disrupted from the fringe of southern lands. Reliable accounts have reached us of vessels frequently running down several degrees of longitude sadly hampered by meeting islands of ice, and especially of one ship being constantly surrounded with icebergs in the corresponding latitudes to those of London and Liverpool, extending nearly the whole distance between the meridians of New Zealand and Cape Horn; indeed, accumulated records point to the conclusion that, on the whole circumference of the globe south of the 50th parallel, icebergs, scattered more or less, may be constantly fallen in with during the southern summer.

The Antarctic voyages of D'Urville, Wilkes, and James Ross assure us of the origin and character of these ice-masses which dot the southern seas. Each of these voyagers was opposed in his progress southward (D'Urville and Wilkes on the 65th parallel, Ross on the 77th) by barrier-cliffs of ice. Ross traced this barrier 250 miles in one unbroken line; he describes it as one continuous perpendicular wall of ice 200 to 100 feet high above the sea, with an unvarying level outline, and probably more than 1000 feet thick—“a mighty and wonderful object.” Ross did not consider this ice-barrier as resting on the ground, for there were soundings in 2500 feet a few miles from the cliffs; Wilkes also sounded in over 5000 feet only a short distance from the barrier.

There is singular accord in the descriptive accounts by Wilkes and Ross of this ice-region; they both dwell on the differences in character of Antarctic from Arctic ice-formation, on the tabular form of the upper surface of the floating icebergs and their striated appearance, on the extreme severity of the climate in mid-summer, on the low barometric pressure experienced, and express equal wonderment at the stupendous forces necessary to break away the face of these vast ice barriers, and the atmospheric causes necessary for their reproduction.

From the drift of this disrupted ice we have fair evidence of a great bodily movement of the waters northward, for it must be remembered that icebergs have been fallen in with in the entire circumference of the southern seas, and that they are pushed in the South Atlantic Ocean as far as the 40th parallel of latitude, in the South Indian to the 45th parallel, and in the South Pacific to the 50th parallel.

In the discussion of Ocean Circulation it has been assumed that water flows from Equatorial into Antarctic areas; there is no evidence, so far as I am aware, that warm surface water in the sense implied is found south of the 45th parallel. Surface stream movement northward and eastward appears to be that generally experienced in the zone between the Antarctic circle and that parallel. With, then, this great bodily movement northward of Antarctic waters included certainly between the surface and the base, or nearly so, of these tabular icebergs (and thus representing a stratum certainly some thousand feet in thickness) the question arises, How and whence does the supply come to fill the created void? Sir Wyville Thomson, the leader of the ‘Challenger’ scientific staff, in one of the later of the many able reports he has forwarded to the Admiralty, furnishes, I think, a reasonable answer. Stating first his views as derived from study of the bottom temperature of the Pacific Ocean generally, he writes:—‘We can scarcely doubt that, like the similar mass of cold bottom-water in the Atlantic, the bottom-water of the Pacific is an extremely slow indraught from the Southern Sea.’ He then gives the reason, “I am every day more fully satisfied that this influx of cold water into the Pacific and Atlantic Oceans from the southward is to be referred to the simplest and most obvious of all causes, the excess of evaporation over precipitation of the land hemisphere, and the excess of precipitation over evaporation in the middle and southern parts of the water-hemisphere.”

Before following up the great northward movement of Antarctic waters, I would draw attention to a physical feature in connexion with tidal movements, which possibly may be one of the many links in the chain of causes affecting Ocean Circulation. The mean tide-level (or that imaginary point equidistant from the high- and low-water marks as observed throughout a whole lunation) has been assumed as an invariable quantity; our Ordnance Survey adopts it as the zero from which all elevations are given, the *datum level* for Great Britain being the level of mean tide at Liverpool. For practical purposes, at least on our own shores, this mean sea-level may be considered invariable, although recent investigations of the tides at Liverpool and Ramsgate indicate changes in it to the extent of a few inches, which changes are embraced in an annual period, attaining the maximum height in the later months of the year; these have been assumed as possibly due to meteorological rather than to the astronomical causes involved by tidal theory.

From an examination of some tidal observations recently made near the mouth of Swan River, in Western Australia, during the progress of the Admiralty survey of that coast, there appears to me evidence that in this locality—open, it will be remembered, to the wide southern seas—the sea-level varies appreciably during the year; thus the greatest daily tidal range in any month very rarely exceeds 3 feet, but the high- and low-water marks range during the year 5 feet. The higher level is attained in June, and exceeds the lower level, which is reached in November, by one foot or more. At Esquimalt in Vancouver Island, fairly open to the North Pacific Ocean, there are indications of the sea-level being higher in January than it is in June; and a distinct excess of the mean level of the tide by several inches in December and January, as compared with the summer months, was traced by the late Captain Beechey, R.N., at Holyhead (see Phil. Trans. 1848). If this surface-oscillation is a general oceanic feature (and some further proofs indirectly appear in the Reports of the Tidal Committee to this Association for 1868, 1870, 1872, to which I have just referred; for mention is also made of a large annual tide of over three inches, reaching its maximum in August, having been observed at Cat Island, in the Gulf of Mexico), we may have to recognize this physical condition—that the waters of the southern hemisphere attain a high level at the period of the year when the sun is to the north of the equator, and that the northern waters are highest at the period when the sun is to the south of the equator. This is a question of so much interest that I propose again to revert to it.

Variations in the sea-level have been observed, notably in the central parts of the Red Sea, where the surface-water, as shown by the exposure of coral reefs, is said to be fully two feet lower in the summer months than in the opposite season; these differences of level are commonly assigned to the action of the winds.

Rennell, in his Investigation of the Currents of the Atlantic Ocean, states, on what would appear reliable authority, that on the African Guinea coast the level of the sea is higher by at least six feet perpendicular in the season of the strong S.W. and southerly winds (which winds blow obliquely into the Bay of Benin between April and September, the rainy season also) than during the more serene weather of the opposite season—the proof being that the tides ebb and flow regularly in the several rivers during the period of strong S.W. winds, but that in the other season the same rivers run ebb constantly, the level of the sea being then too low to allow the tide-waters to enter the mouths of the rivers. It is possible that the cause, here and elsewhere, may in part be cosmical, and neither meteorological nor astronomical in a tidal sense.

These several facts in relation to the variations in level of the surface of the ocean are interesting, and point to new fields of observation and research.

Another physical feature connected with the ocean-level is deserving consideration; I refer to the effect of the pressure of the atmosphere. On good authority we know that the height of high water in the English Channel varies inversely as the height of the barometer; the late Sir John Lubbock laid it down as a rule that a rise of one inch in the barometer causes a depression in the height of high water amounting to seven inches at London and to eleven inches at Liverpool. Sir James Ross, when at Port Leopold in the Arctic seas, found that a difference of pressure of ·668 of an inch in the barometer produced a difference of 9 inches in the mean level of the sea, the greatest pressure corresponding to the lowest level. These results appeared to him to indicate "that the ocean is a water-barometer on a vast scale of magnificence, and that the level of its surface is disturbed by every variation of atmospheric pressure inversely as the mercury in the barometer, and exactly in the ratio of the relative specific gravities of the water and the mercury." When we consider the exceptionally low barometric pressure prevailing in the southern seas, and the comparatively low pressure of the equatorial ocean-zones as compared with the areas of high pressure in the oceans north and south of the equator (the latter features a late development by Mr. Buchan), these characteristic conditions of atmospheric pressures cannot exist without presumably affecting the surface-conditions of adjacent waters.

There is yet one more point in connexion with the ocean-circulation which I venture to think has not received the attention it demands; this is, the economy of those currents known as "counter-equatorial." Their limits are now fairly ascertained, and are found to be confined to a narrow zone; they run in a direction directly opposite to, and yet side by side with, the equatorial streams of both the Atlantic and Pacific oceans. We know that they run at times with great velocity (the 'Challenger' experienced fifty miles in a day in the Pacific Ocean), and occasionally in the face of the trade-wind—and that they are not merely local, stretching as they do across the wide extent of the Pacific, and in the Atlantic, during the summer months of our hemisphere, extending nearly across from the Guinea coast to the West-India Islands. They have, too, this significant feature, that their narrow zone is confined to the *northern side alone* of the great west-going equatorial currents, this zone is approximately between the parallels of 7° and 10° N., and thus corresponds with the belt of greatest atmospherical heat on the earth's surface.

That the functions of the countercurrents in the physics of the ocean are important, must, I think, be conceded. They appear to act on their eastern limits as feeders to the equatorial currents, and, from the seasonal expansion, which has been well traced in the Atlantic, are probably more immediately associated with some oscillatory movement of the waters following, though perhaps only remotely connected with, the sun's movements in declination.

A brief summary of the thermal conditions of the oceanic basins will now enable us to review the salient features of Ocean Circulation, and the more immediate scientific position the question has assumed.

In all seas within the torrid and temperate zones, provided any given area is not cut off by submarine barriers from a supply of polar or glacial water, the sea-bed is covered by a thick stratum of water the temperature of which is confined between 32° and 35° F. In the Pacific Ocean this cold stratum must be derived from antarctic sources, for the opening of Behring Strait is too small to admit of an appreciable efflux of arctic waters. In this ocean the cold stratum obtains generally at depths below 9000 feet from the surface, with an almost invariable isothermal line of 40° F. at from 2500 to 3000 feet from the surface. Similarly, in the Indian-Ocean basin the cold stratum at the bottom is derived from antarctic sources, for the temperature of 33°.5 F. underlies the hot surface-waters of the Arabian Gulf.

In the South Atlantic, antarctic waters, with a bottom-temperature of 31° to 33°.5 F., certainly cross the equator; the bed of the North-Atlantic basin then warms up to 35°; marked diversities in both the temperatures and thickness of the successive layers of water from the surface downwards are found, and in the central parts of the basin it is not until the vicinity of the Faroe Islands is reached that arctic waters of an equivalent temperature to those from antarctic sources are experienced.

Turning now to the scientific aspect of the question:—

The doctrine of a general Oceanic Thermal Circulation assumes two general propositions:—1, the existence of a deep under-flow of glacial water from each pole to the equator; and, 2, the movement of the upper stratum of oceanic water from the equatorial region towards each pole, as the necessary complement of the deep polar under-flow—this double movement being dependent "upon the disturbance of hydrostatic equilibrium, constantly maintained by polar cold and equatorial heat."

Proposition 2, in its general application as to the movement of surface-waters, is unquestionable; but that of a deep under-flow from the poles, as a necessary complement, remains open to doubt. Proposition 1, in its wide generality, must, from what we know of the Pacific, be confined to the Atlantic Ocean, and it appears to me that it is on the interpretation of the movement of the waters in its northern basin that the hypothesis of a vertical circulation, and the potency of thermal agency in bringing it about, must be judged.

We have followed the movements of antarctic waters in the Atlantic to the 40th parallel, as illustrated by the progress of icebergs; we know that the movement deflects the strong Agulhas current, and that the cold waters well up on the western shore of the South-African continent, cooling the equatorial current near its presumed source; the thrusting power of this body of water is therefore great. About the equator it rises comparatively near to the surface. But we now come to another and distinct movement, the equatorial current; and on this, I apprehend, the material agency of the winds cannot be denied, in forcing an enormous mass of surface-water from east to west across the ocean. The Gulf-stream results; and the comparative powers of this stream, as especially influencing the climate of our own and neighbouring countries, together with the forces at work to propel its warm waters across the Atlantic, have become the controversial field for the upholders of horizontal and vertical circulation. The one hypothesis assigns to the Gulf-stream all the beneficent power of its genial warmth, extending even beyond the North Cape of Europe, which has been conceded to it from the time of Franklin. The other hypothesis reduces its capacity and power, considers that it is disintegrated in mid Atlantic, and that the modified climate we enjoy is brought by prevailing winds from the warm area surrounding the stream, and to this has been more recently added, 'by the heating-power of a warm sub-surface stratum whose slow northward movement arises from a constantly renewed disturbance of thermal equilibrium between the polar and equatorial portions of the oceanic area.'

Without denying the active power of this disturbed thermal equilibrium—although in this special case it is an abstraction difficult to follow—and giving due weight to the many cogent facts which have been brought forward in support of both views, there appears to be still a connecting link or links wanting to account for the southern movements of arctic waters, which movements, to me, are even more remarkable as physical phenomena than the translation of the warm waters from the Gulf-stream area to a high northern latitude.

This movement of arctic waters is forcibly illustrated by the winter drifts down Davis Strait of the ships 'Resolute,' 'Fox,' 'Advance,' and a part of the crew of the 'Polaris,' when enclosed in pack ice, exceeding in some cases a thousand miles, similarly by the winter drift of a part of the German expedition of 1870, down the east side of Greenland from the latitude of 72° to Cape Farewell. If to these examples we add the experience of Parry in his memorable attempt to reach the North Pole from Spitzbergen in the summer of 1827, it must be inferred that a perennial flow of surface water from the polar area into the Atlantic obtains, and, judging from the strength of the winter northerly winds, that the outflow is probably at its maximum strength in the early months of the year.

When we further know that the northern movement of warm waters gives *in winter* a large accession of temperature to the west coast of Scotland, to the Faroe islands and, extending to the coasts of Norway, as far as the North Cape, the consideration arises whether this onward movement of waters from southern sources is not the immediate cause of displacement of the water in the polar area and its forced return along the channels indicated by those winter drifts to which I have referred.

That some unlooked for and unsuspected cause is the great agent in forcing southern waters into the Atlantic polar basin has long forced itself on my conviction, and I now suspect it is to the cause producing the annual variations in the sea-level (for, as I have mentioned, indications exist of the seas of the northern hemisphere having a higher level in winter than in summer) that we must direct our attention before the full solution of Ocean Circulation is accepted.

The facts of the annual changes of sea-level, whatever they may ultimately prove, have hitherto ranged themselves as a part of tidal action, and so escaped general attention. Physicists well know the complication of tidal phenomena, and, if one may be permitted to say, the imperfection of our tidal theory, certain it is that the tides on the European coasts of the Atlantic are so far abnormal, that one of our best authorities on the subject (Sir William Thomson) describes them (in relation, I assume, to tidal theory) as "irregularly simple," while the tides in all other seas "are comparatively complicated but regular and explicable." However this may be, specialists should direct their attention to the disentanglement of the variations in the sea-level from tidal action simple, and our colonies, especially those in the southern hemisphere, would be excellent fields for the gathering-in of reliable observations.

I am unwilling to leave the subject without tracing some of the consequences that might be fairly considered to follow this assumed change of level in the North-Atlantic basin. We can by it conceive the gradual working-up of the warmed water from southern sources as the winter season approaches, including —the expansion of the Gulf-stream in the autumn months, the consequent welling-up of a head of water in the enclosed and comparatively limited area northward of Spitzbergen, Greenland, and the broken land westward of Smith Sound, the forced return of these glacial waters, their greatest volume seeking the most direct course, and thus working down the Labrador coast charged with ice and passing the American coast inside the Gulf-stream, while the smaller volume, reaching the higher latitudes in mid Atlantic, interlaces with the warm barrier waters, causing those alternating bands of cold and warm areas familiar to us from the 'Lightning' and 'Porcupine' observations, and which are now being worked out by the Norwegian exploring expedition in the Government ship 'Vöringen.'

We can further conceive that the large function of the 'counter-currents' on the north margin of the great equatorial streams is to act as conduits for the surcharged waters of the northern oceans consequent on the gradual changes of level. The Atlantic counter-current, we know, expands markedly in the autumnal season, and there may be some connexion between this expansion and the high level of the waters said to exist in the Gold-Coast and Guinea bights at the same season.

We are thus, as it appears to me, now only on the threshold of a large field of inquiry bearing on the Physical Geography of the Sea. But we have this advantage, the admirable discussions which have taken place in the past few years, productive as they have been of the marshalling hosts of valuable facts, will lighten the labours of those who engage in the prosecution. Science is deeply indebted to, and I am sure he honours those who have so earnestly worked on the opening pages of the coming chapter on Ocean Circulation.

Unwillingly I turn from this interesting subject; but the demands on my time and your patience are imperative; and, following precedent, it is incumbent on me briefly to bring under the review of the Association the latest unrecorded incidents in geographical progress or research.

There is one absorbing topic which, in the course of a few weeks or even days, may attract general interest. I refer to accounts of our Arctic Expedition. It is possible that, while I am now addressing you, the ships 'Alert' and 'Discovery,' favoured by fine seasons, may have in their endeavours to reach high northern latitudes accomplished all that human skill and energy can do, and, by fortuitous circumstances, secured their return southward through Smith Sound with the same facility, we have reason to hope, as they entered what we suppose to be that notable gateway to the Pole. If so, they are now fairly in Davis Strait homeward bound. We must not regard this estimate of progress as visionary; for, the conditions being favourable, the time at the disposal of the voyagers is ample. It is the varying conditions of arctic seasons we must remember that baffle the forecasts of the most experienced arctic experts.

Should unfavourable conditions, or the decision of the Chief, detain the ships another year in their icy quarters, we have reason to hope that advices will reach us of their whereabouts in the spring of this year. The spirited enterprise of the well-trained arctic navigator, Allan Young, supported as he has been by the Government, offers a sure guarantee that the leaders Nares and Stephenson will be ably seconded in their efforts to keep up communication with their countrymen. Here again we must not forget that baffling conditions may defeat the intentions of the command as to communicate in time with the depôts at the portals of Smith Sound.

This prolonged banishment from intercourse with the outer world, however, was a contingency anticipated and provided for by that ably Committee of arctic officers who, with a full sense of their responsibility, so fully advised the Government in every phase of this national undertaking. A Parliamentary paper, published during this session, gives the fullest particulars relating to the progress of the expedition and the steps which have been taken to communicate with their depôts. There is a long chain of contingencies to be attended to, as will be seen on reference to the interesting details therein given; but I venture to think that not a link is missing, either in the conception or in the means provided, to bring the undertaking to a successful issue.

There is one feature to be kept in view—which from the exceptional conditions of ship-navigation in the icy regions of the far north is rarely realized, unless by those who have had actual experience in polar service, and it is this, that between the time of the disruption of the old ice in August and the formation of the new in September, there exists a very short period when ships are free to move. This period of open or partially open water may be shortened by unfavourable circumstances, and *vice versâ*, it may be assumed, however, that in a straight fairway channel such as Smith Sound, it almost always does occur, and as the return southward, on account of the drift, is always more easily accomplished than the advance north, the great probability is that, if the ships remain out another year, it will be the result of design rather than accident.

By the Parliamentary papers relating to the expedition it will be seen that, in the event of the non-arrival of the 'Alert' and 'Discovery' during the autumn of this year, a relief ship will be despatched to a rendezvous in Smith Sound during the summer of 1877.

With regard to *Africa* exploration and discovery have proceeded with accelerated strides during the past few years. Even since the recent date of Cameron's remarkable journey across the continent important additions have been made to the rapidly filling-up map of the interior. Most of these additions relate to the great lakes, regarding which our knowledge was previously very incomplete and unsatisfactory. Thus Mr. Young, the experienced Zambesi traveller, who undertook last year to lead the Scotch Missionary party to Lake Nyassa, has succeeded, after establishing the missionary settlement 'Livingstonia' at the southern end of the lake, in reaching in a steam launch the northern end of this great freshwater sea, finding it to be fully one hundred miles longer than was previously believed. His journey was made in February of the present year, and in the following month the still more imperfectly known lake, Albert Nyanza, was successfully navigated by two boats under Signor Gessi, who was despatched for this purpose by Colonel Gordon, the present Governor of the new equatorial province of the Khedive's dominions. The details of Signor Gessi's interesting exploration, communicated by himself to the President of the Royal Geographical Society, have only recently reached England, and it is proposed to read them in the course of the present meeting.

A third and equally important exploration of the same class is that performed during the same early months of the present year by that energetic traveller Mr. Stanley. After circumnavigating the much larger neighbouring lake, Victoria, and proving Speke's much disputed estimate of its dimensions to be approximately correct, he pushed his way across the difficult tract of country separating the Victoria and the Albert lakes, reaching the shores of the latter in the middle of January. Less fortunately situated than Signor Gessi, who embarked on the lake two months later, Stanley was unable to launch his boat on the then unexplored southern portions of its waters. A comparison of the accounts of the two travellers shows that we are yet far from knowing the true dimensions of this great sheet of water. Signor Gessi in fact did not reach its southern extremity, and as Mr. Stanley appears to have struck its shores at a point about thirty miles further south than the limits marked by the Italian traveller, the lake must be considerably longer than 140 miles as estimated by the latter. Stanley subsequently proceeded south and explored the Kitangulé river of Speke, thence striking for Lake Tanganyika, the examination of which he intended to complete.

New Guinea has of late attracted some attention both at home and in the Australian Colonies, rather, however, from political than geographical considerations. Our interest is of course in the latter, and I am glad the meeting will have the advantage of the presence of a gentleman (Mr. Octavius Stone, recently arrived in England) who has distinguished himself in the exploration of the south-eastern shores of this distant, little-known, and barbarous region; to him we must refer for the latest geographical facts.

With your permission we will now enter on the subject-matter before the Meeting.

On a new Route to the Sources of the Niger. *By* A. BOWDEN.

On the Specific Gravity of the Surface-water of the Ocean, as observed during the Cruise of H.M.S. 'Challenger.' *By* J. Y. BUCHANAN.

On a new Deep-sea Thermometer. *By* J. Y. BUCHANAN.

On his Journey through Equatorial Africa.

By Commander V. L. CAMERON, *R.N., C.B.*

The author said that soon after entering the country from the east coast he came to a large plateau, 4000 feet in height, encircling Lake Tanganyika, and forming the watershed between the Congo and the streams flowing into Lake Sangora. Another tableland to the south rose to the height of 3000 feet The watershed between the two basins of the Lualaba and the Congo at that part is a large, nearly level country, and during the rainy season the floods cover the ground between the two rivers, and a great portion of it might easily be made navigable. One thing he noticed in Africa was this system of watersheds, dividing the country into portions, each having its own peculiarity, and also that in each there was a difference in the habits of the natives. Within twenty days he crossed the Nsagra Mountains and came upon a level open country where a great quantity of African corn was grown, the stalks of which rose to the height of from 20 to 24 feet. In this country no animal could live except the goat, the tsetse fly being destructive to all others. The principal geological formation was sandstone. A few marches brought him to Ugogo, an extensive plain broken by two ranges of hills, composed of loose masses of granite piled together in the wildest confusion. The soil was sandy and sterile. Coming to the country of the Ugari he found a tribe almost identical with Unyamwesi The principal streams of this district fall into the Mulgarazi. Unyamwesi was the commencement of the basin of the Congo He believed that the natives of Unyamwesi were of the Malay race; they had crossed a great deal with negroes, and had lost the distinctive colour and distinctive marks of the race, but their features were much the same as the dominant races in Madagascar Ugaro is a large plain very nearly quite flat The people here were different from the Unyamwesians, they had not got the same features or the same tribal marks. After passing over the mountains of Komendi, which are an offshoot of the mountains round the south end of Tanganyika, they came to a fertile land, much of it laid waste by the ravages of a neighbouring tribe. All the mountains in that district were of granite. There was there a large quantity of salt, and what was remarkable was that the rivers ran perfectly fresh through soil which, when the natives dug wells, gave water which was full of salt At Ujiji the people are of a different race from those already described, as they shave their hair differently and have not the same features. Along Lake Tanganyika in some places there were enormous cliffs and hollows of rugged granite lying in loose boulders, in other places the cliffs were of red sandstone, and in others a sort of limestone and dolomite At one place he saw exposed on the shores of the lake large masses of coal. Passing down to the south end of the lake, he found it regularly embedded in cliffs 500 to 600 feet high, with waterfalls discharging themselves down the face

Travelling along the side of the lake he came to the Lukogo, a large river more than a mile wide, but partly closed by a sort of sill on which a floating vegetation was growing, a clear passage, however, being left of about 800 yards. After proceeding some four miles up the river, the author's boat got jammed amongst the floating vegetation which grows to the thickness of two or three feet, and it was with difficulty the boat was extricated. The Kasongo country was next reached, the principal characteristic of which was the extraordinary trees, of which boats a fathom wide are sometimes made. Crossing the mountains of Bambara he arrived at Mamyuemba. Here he found the race entirely different from any thing he had yet seen. The houses were differently built, the people were differently armed, dressed their head differently, and there was no tattooing to speak of. The villages were built in long streets thirty or forty yards wide, two or three streets being alongside each other, and a space left between the houses, which were of reddish clay, with sloping thatched roof—the only houses of that description he saw in the interior of the country. All the Mamyuembans are cannibals. Journeying northwards, but still in Mamyuemba, a district was reached where iron was very plentiful, and where large forges were at work. Many of the spears and knives which they turned out looked as if finished off by a file or polished by some means, although all done by hand-forging and patient labour. The Lualaba River was next reached, which is about 1800 yards in breadth. The southern shore is occupied by a tribe called the Wagenga, who do the whole carrying business of the river, being the only canoe proprietors, who take for pay the products of the country to the different markets. The young women make immense quantities of pottery in the mud and back water, which they exchange for fish.

After referring to a country between Nywangi and Loanni, where a palm-oil grows in great profusion, the author said that he traversed Kilemba, and reached Lake Kigongo. This lake is covered with floating vegetation, on which the people build their houses, cut a space round about them, and so transform their habitations into floating islands, so that when desirable they change the locality from one place to another. Coming to the coast he passed through one of the most magnificent countries in the world to look at, possessing a climate in which any European might live. The Portuguese had been settled in this neighbourhood for thirty years. The whole of this country was just one vast slave-field. In the country there was a vast mineral wealth and an ordinary population that, with education, might be rendered very industrious instead of carrying on a continual warfare against each other for the purpose of obtaining slaves.

On his Recent Explorations in N. W. New Guinea.
By Signor G. E. CERRUTI.

After several visits to the islands and part of the mainland on the north, the author was in 1869 sent out by Count Menabrea for the purpose of making investigations preliminary to the formation in New Guinea of a penal settlement, he secured at the same time means for turning his expedition to profit geographically. He believed that a great part of the region from the Xulla Islands to New Guinea, and perhaps more to the north, had been subject to very important volcanic action in an epoch not very far distant, and one could see the work now going on, the western coast showing gradual subsidence. But whatever the origin of the islands, they were now covered with a vegetation which he had not found equalled in luxuriance in any part of the world. He urged in strong terms the colonization of New Guinea.

Observations on the White Nile between Gondokoro and Appuddo.
By Lieut. W. H. CHIPPINDALL, *R.E.*

On Perak and Salangore. *By* W. BARRINGTON D'ALMEIDA.

Observations on the Conventional Division of Time now in use, and its Disadvantages in connexion with Steam Communications in different parts of the World, with Remarks on the desirability of adopting Common Time over the Globe for Railways and Steam-Ships. *By* SANDFORD FLEMING.

On the Site of the Grave of Genghiz Khan. *By* Professor FORBES.

On the Samoan Archipelago. *By* LITTON FORBES, *M.D.*

On Akem and its People, West Africa. *By* Capt. J. S. HAY.

On the Geological Distribution of Oceanic Deposits. *By* J. MURRAY.

These deposits were stated to be of three classes:—first, those which were found all round the continents and islands existing over the world, without any exception, but which varied according to the places where they were found; secondly, those found at from 200 to 300 miles from the land, consisting of shell and lime deposits, and covering most of the bed of the ocean; thirdly, those existing at other depths, and which were of siliceous character. Observations had shown that a curious relation existed between the nature of the deposits and the depth of the water. It was also pointed out that in the neighbourhood of volcanic islands, and in no other places, were found large deposits of manganese, coating the shells and other things brought up from the bottom.

On the Islands of the Coral Sea. *By* KERRY NICHOLS.

The Coral Sea embraces that portion of the Pacific Ocean extending from the south of New Guinea, westward to the coast of Australia, southward to New Caledonia, and eastward to the New Hebrides. The New Hebrides' banks and Santa-Cruz Islands, the author said, are an almost continuous chain of fertile volcanic islands, extending for a distance of 700 miles, between the parallels of 9° 45' and 20° 16' south latitude, and the meridians of 165° 40 and 170° 33' east longitude. Espiritu Santo, the largest island of the archipelago, was seventy-five miles long and forty miles broad. The geological formation of the islands was composed of volcanic and sedimentary rocks. The chain of primary volcanic upheaval might be traced running in a general course longitudinally through the islands always in their longest direction, the axis of eruption being marked by active and quiescent volcanoes. On the north end of the island of Vanu Lava there were extensive springs of boiling water, solfataras, and fumaroles. The hot springs were of two kinds:—some were permanent fountains where water was in a constant state of ebullition, others were only intermittent, and the water became heated at certain intervals, when it varied from a tepid degree of heat to boiling-point. The physical features of the islands were remarkably bold, and betokened at first sight their volcanic origin. The plains, tablelands, and valleys of the mountain region were, many of them, of considerable extent.

On a Journey across Finland, from Ellenborg to Archangel viâ Kemi. *By* Rev. J. PATERSON.

On Travels in Tunis in the Footsteps of Bruce.
By Col. R. L. PLAYFAIR, *H.M. Consul-General in Algeria.*

The paper gave a narrative of the author's observations made in the course of a journey in Tunis over places visited by Bruce about 1763. There had been recently put into Col. Playfair's hand for publication a large number of Bruce's sketches, of which his Barbary sketches were, he said, the most interesting, forming about 120 sheets of drawings, completely illustrating the archæology of North Africa. In these circumstances, the author had determined to follow Bruce in his journey, and to satisfy himself as to the present condition of those interesting ruins, which were almost unknown to the modern traveller.

On some Points of Interest in the Physical Conformation and Antiquities of the Jordan Valley. By Professor PORTER.

The general geological structure of the valley, the author said, was lime, and of the same age as the basin of the Sea of Gallilee, and its surface was flat. The breadth varied from three to ten miles, extending a little towards the east, and from the nature of its thick alluvial covering, it was of more recent formation than the mountains, of which the soil was the deposit, the valley having been at one time apparently a lake. The River Jordan, as it at present existed, could have had nothing to do with the formation of the valley itself. He recommended to the notice of men of science that geological remains on the site of Sodom and Gomorrah pointed to an explosion of bitumen much later than the ordinary geological formation, and probably within the historic period.

Notes on the River Putumayo or Içá, South America. By A. SIM

On his Recent Journeys in New Guinea. By OCTAVIUS STONE.

The island extends in a south-easterly direction for a distance of over 1400 miles, having a maximum width of 450 miles and a minimum of only 20. The neighbourhood of the Baxter River and the entire shores to the west of the Papuan Gulf, for an average of 100 miles inland, were low and more or less swampy, being intersected by watercourses and covered with forests of mangrove-trees. This part of the country was thinly populated by the Dandé Papuans, who in consequence were subjected to periodical raids from the adjoining islands of Borgu, Saibai, and Daun, the invaders generally returning victorious with the heads or jaw-bones of their slaughtered victims. The only trace of cultivation he saw was 80 miles up the river, where a space of six acres had been neatly fenced round and planted with yams, taras, sugar-cane, and tobacco. Outside the enclosure were two or three uninhabited bark huts, which appeared to afford shelter to these roving people, in which they prolonged their stay as game was more or less plentiful. Traces of wild boar and kangaroo were observed in the Upper Baxter. No other large animal was known to exist. They were hunted with the bow and barbed arrow, while the war-arrows were poisoned by steeping in the putrid carcase of a victim until sufficiently saturated. The district of the Baxter River contrasted strikingly with the Fly River discovered by Capt. Evans, whose banks for 60 miles swarmed with human beings. The author's impression of the western coast was that it would prove a grave to such Europeans as should choose to reside there. This part of the country was inhabited by the Papuan race, a dark race of people, though not so dark as the Australian negro, and one of cannibal propensities. The eastern peninsula, on the other hand, was inhabited by the Malay race. Of this race the author thought they had come to New Guinea from islands further east, some of them making the change at a comparatively recent date. This race was far above the savage, both in intellectual and moral attributes. They were cultivators of the soil, each having his own plantation, and strongly opposed to the cannibalism and polygamy which obtained among their western neighbours the Papuans. The women, too, of the Malay race were not debased as among the dark race, but mixed with the men, with whom they shared the management of public affairs. The Owen Stanley mountains ran through the centre of the country, from south to north; and the east country was, on the whole, favourable to cultivation, and probably possessed great mineral wealth. It accordingly offered sufficient inducement for colonization, but colonization, if attempted, would require to be set about with much previous consideration, owing to the peculiar situation of the peninsula and the circumstances of the people.

On the Temperature obtained in the Atlantic Ocean during the Cruise of H.M.S. 'Challenger.' By Staff-Commander Tizard, R.N.

Over a great portion of the Atlantic the bottom temperature has this peculiarity:—If the depth be less than 2000 fathoms, we find the temperature at the bottom lower than that of any intermediate depth; but when the depth exceeds 2000 fathoms, we find that the bottom temperatures are nearly the same as they are at that depth. This holds good for three fourths of this ocean. In the remaining fourth the temperature obtained at the bottom is much lower than in the other parts; and this fourth is not at either extreme, where there is a large current of surface cold, but occupies the whole of the western portion of the South Atlantic as far north as the Equator. The results of these temperatures may be classified thus:—If an imaginary line be drawn from French Guiana to the westernmost island of the Azores, and from thence north on the western side of this line, the bottom temperatures at depths exceeding 2000 fathoms are 35°, that is, taking the mean of all the temperatures obtained, which differ but slightly. On the eastern side of this line the bottom temperatures are 35°.3, and this uniform temperature appears to extend as far south as Tristan d'Acunha, as the German frigate 'Gazelle' obtained similar bottom temperatures eastward of the line joining that island with Ascension to the southward of a line joining Tristan d'Acunha with the Cape of Good Hope. The bottom temperatures are decidedly colder between the eastern coast of South America and a line joining Tristan d'Acunha and Ascension Island; and from the Equator to the southward the bottom temperatures were invariably colder than at any intermediate depth. These temperatures varied from 31° to 33°.5, that is, when the depth exceeds 2000 fathoms, and temperatures of less than 33° were found as far north as the Equator, while a few miles northward this bottom temperature was 35°. It therefore appears that in the western portion of the South Atlantic the highest bottom temperature is less than the lowest obtained elsewhere in this ocean, excepting where the very low result of 29° was found by the 'Porcupine' in 1869 between the Faroe Isles and the north extreme of Scotland. The question thus arises as to the causes which confines this cold water to the bottom portion of the western half of the South Atlantic. The examination of the soundings which had been taken in this ocean, combined with the results of their temperature, leads to the conclusion that there is a series of ridges dividing its bed into two basins, one of which occupies the whole of the western portion of the North Atlantic, while the other extends the whole of the length of the ocean on its eastern side, and that the cold water in the western portion of the South Atlantic is owing to there being no obstruction between the bed of this portion of the ocean and the bed of the Antarctic basin; and from the results of the serial temperatures' soundings it would appear that these ridges cannot exceed 1050 or 2000 fathoms in depth. To ascertain the thermal condition of the Atlantic (from the surface to the bottom), serial temperatures were obtained in the 'Challenger' at 150 positions, observations having been made at each 100 fathoms to 1500 fathoms in depth, and frequently at, say, 10 fathoms to 200 fathoms in depth, at each of these positions. An examination of these temperatures shows that between the parallels of 40° N. and 40° S. there is a much larger amount of warm water in the North than in the South Atlantic, and that in the equatorial regions the isotherm of 60° is much nearer the surface than in the temperate zones, but that the isotherms below 60° are at nearly as great a depth at the Equator as in any part of the South Atlantic, especially at the isotherm of 40°, and that between the parallel of 30° and 40° N. latitude the isotherm of 60° occupies a depth of 300 fathoms over an area of 1,200,000 square miles, while the average depth of this isotherm between the parallels of 30° and 40° S. latitude is 160 fathoms; also that the isotherm of 40°, which is at an average depth of 800 fathoms across the North Atlantic, between the parallels of 30° and 40° N. latitude, occupies only half that depth in any part of the South Atlantic. This phenomenon may be explained in the following manner:—The power of the sun indirectly heating the water below the surface appears not to extend below 100 fathoms even in the tropics; and this power decreases as the higher latitudes are reached, until a position is attained where the temperature is that of the freezing-point of salt water. As salt water at its temperature of congelation is denser than at any higher temperature, its weight would cause it to sink, and it would in time, did no other cause intervene, occupy the whole of the space in the ocean not influenced by the sun's heat. But in considering the effect of the heat imparted to the surfaces, we have also to consider the effect of evaporation and precipitation. In the equatorial regions evaporation is rapid, so that the surface-film would become cleared through increased salinity were it not for the increased temperature and large precipitation, as well as to its being transported by the friction of the trade-winds and earth's motion to the westward. This surface-film, constantly moving westward in the equatorial regions, meets in the Atlantic with an obstructing point of the South-American continent, which directs it to the northward, so that the greater part of the water directly heated by the sun's rays in the tropical regions is forced into the North Atlantic. As the salinity of this water is greater than that of the subjacent layers, and its increased temperature only renders it less dense, directly a portion falls in temperature in the colder regions of the temperate zone, the surface-film sinks and imparts heat to the water beneath. Consequently the isotherms will be found at greater depths where the heated surface-films are constantly descending than when, owing to their being less dense than the subjacent layers, they remain on the surface.

ECONOMIC SCIENCE AND STATISTICS

Address by Sir GEORGE CAMPBELL, *K.C.S.I., M.P., D.C.L., President of the Economic Section.*

I FEEL a difficulty in undertaking the Presidency of this special and important Department of the British Association, in this great city, which contains so many men masters of so many branches of economic subjects. But, Scotchman as I am, I have felt that I could not decline the honour proposed to me in the commercial capital of my own country; and I remember with pride that perhaps in no place in the British Empire could economic subjects be discussed with so great advantage. Other places have special industries. Glasgow has many, and she excels in them all.

I understand it to be the object of the Association that in the treatment of the subjects presented to us we should study, in this as in other departments, to follow as far as may be a strictly scientific method of inquiry, not lapsing into the discussion of political details, but attempting to ascertain the principles on which economic results are founded, and to define the main lines of economic truth. It may not always be possible to draw the boundary between science and practice; but I am sure that we shall all try as much as possible to avoid matters which involve party or personal questions, and to maintain a calm and scientific attitude in our treatment of the many subjects which come within the range of this Section.

The Section was originally called that of "Statistics;" and all economic inquiry must be based on or tested by Statistics. At first sight Statistics expressed in figures might seem to constitute the most exact of sciences; but in practice it is far otherwise. In nothing is so great caution necessary; there is too great temptation to reduce to figures facts which are themselves not sufficiently ascertained; too often an exactness is claimed for these figured results which is altogether fallacious and misleading. In fact there is a use and an abuse of figures; and one is sometimes tempted to sympathize with the cynical philosopher who said that nothing is more misleading than facts, except figures. It is especially necessary to distinguish between figures which are really ascertained, and those which are merely drawn by deductions from rough and conjectural facts. A false appearance of exactness should not be given to these latter For instance, if we take the geographical area of a country to be so much, and assume the density of population to be at a certain rate per square mile, we may work out a very precise figure, and yet in reality the result is not at all precise

There is very often fear that Statistics are sought out and adapted to suit a preconceived theory. Another misuse of Statistics is this, that when they are used to test certain capacities and qualifications work is directed and shaped to meet the statistical test, and the results thus obtained become misleading. In such a case it is necessary very frequently to change the form in which the statistical test is applied

Bearing in mind, however, the necessity of guarding against abuse, there can be little doubt that statistical science is one of the most important instruments and necessities of our time, especially in this country, in which we are somewhat deficient in that science First, we require statistics for the direct ascertainment of facts for practical use, for instance, the statistics of production Agricultural and manufacturing statistics are of the greatest practical importance to the farmer and the manufacturer. We are almost wholly destitute of agricultural statistics. How great is the contrast in America and other countries, where great attention is paid to these subjects, and every farmer in the country is kept informed of very much that it is most important for him to know!

But there is a second and almost more important use of Statistics, viz. the cultivation of economic science by the inductive method It is by collecting, verifying, and classifying facts that we are able to approach economic truth There was a time when it seems to have been supposed that political economy was a science regulated by natural laws so fixed that safe results could be attained by deductive reasoning. But since it has become apparent that men do not in fact invariably follow the laws of money-making pure and simple, that economic action is affected by moral causes which cannot be exactly measured, it becomes more and more evident that we cannot safely trust to a chain of deduction, we must test every step by an accurate observation of facts, and induction from them. This is, it seems to me, the highest function of statistical science we recognize that men are not mere machines whose course may be set and whose progress may be calculated by a simple formula. Men are complicated beings, whose minds and motives of action we do not yet thoroughly understand, we cannot foretell what they will do till we are sure that we know what in fact they actually have done and do in a great variety of circumstances In proportion as we attain that knowledge, we become acquainted with the main agent in economic science, and make advances towards a knowledge of that science

When we seek to understand economic history and economic institutions, it is seldom that all the necessary materials are ready to hand in our own country and our own age. We must search for them far and wide We seek to recover economic history, generally very imperfectly recorded in times when the science was little understood And at the same time there is a kind of contemporaneous history of which very much use may be made. We may observe facts, and may obtain statistics in countries which are in stages of human and economic history very different from our own As the history of plants and animals is recovered from geological records, so we may recover much of human history by studying man in the early, middle, and more advanced stages of civilization. We of this country, who rule over so many lands in so many parts of the world, have special opportunities for this kind of economic study In my own experience I have been particularly struck by the light thrown on our institutions by a comparison with those lately and now existing among the different peoples of India India is in truth a country of many peoples, and there is there infinite material for the human archæologist who would study the earlier phases of human history among the primitive aboriginal tribes, still in what I would call the earlier stages of existence. We may there learn much of the origin of the institutions which we have long come to look on as almost part of our nature—of the earlier forms of property and marriage, and many other things. The fortunate connexion with India of that great scholar, Sir Henry Maine, has led to a great amount of light on the connexion between the East and the West. At present I would only allude to one or two points in what I call the middle history of man, directly leading to our modern institutions, in respect of which I think that much may be learned from observation in India. And in India we are not now left to mere individual observation only. A very substantial commencement has been made towards the introduction of statistical science and the collection of statistics of tolerable value, in that country. For some years past great attention has been paid to this subject by the Government. I may venture to say that I myself, when I held office in that country, have done all that was in my power to promote statistical knowledge; and a number of earnest men have done the like. As usual in the commencement of such inquiries, our difficulty has not so much been to get figures as to keep our statistical figures down to those which are pretty reliable. We are thoroughly aware of the necessity of caution in this respect, and we believe that we are gradually coming to the point when we can say that we have some very valuable statistics on a very large scale.

Of the history and use of local Institutions we may learn very much in India. That country was, locally speaking, one of the most self-governed countries in the world, in native times. In all parts of this island, while the civic constitutions of the ancient Burghs have been preserved, the self-governing institutions of the country at large have almost entirely disappeared, leaving only a few fossil remains to testify to their previous existence. On the continent of Europe the old Communes retain a good deal of vitality. But it is in India under native rule that we see these institutions in full vigour and working order. That little republic, the village community of India, has come to be looked on as an interesting old relic rather than as the subject for modern imitation. In my opinion we may draw from it a very large store of economic knowledge which may be very useful to us. I grieve to say that philistine and self-satisfied as we are, prone as we are to believe that there can be no good thing that is not our own, instead of supporting and cherishing the self-governing Indian Communes, and taking from them an example for our own country, we are permitting them to fall into decay. They owed in fact their cohesion and their durability to pressure from without, to the necessity of the case, which made self-government indispensable to their existence. Our strong arm has removed that external pressure, and in our self-confident spirit we have substituted our pretentious but imperfect and uncertain Courts for the rough but reliable village rule of former days. I believe that the more we introduce into India true economic science, the more it will be apparent that we have taken on ourselves too heavy a burden, that too great centralization is a mistake, and that, in a country where political freedom on a large scale is impossible, the only satisfactory resource is a large measure of the local government to which the people are accustomed.

The tenure of land is another subject on which great light is thrown by Indian experience. After an intimate acquaintance with the tenures which we there find in existence, and those which our system has created, we seem to have before us a picture of the rise and progress of property in land. Putting aside the older forms of property, we have had in India many examples of the feudal tenure of a conquered country by chiefs and subchiefs holding in subordination one to another and ruling over communities of cultivators, some of whom were free and possessed of certain rights and privileges, and others were in a servile position. Among the communities holding land we have manifest traces of the old system of partition and repartition; we have before our eyes the gradual disuse of that old system and the gradual growth of the individual tenure of the lands under the plough with common use of the pasture-lands, the wood, and the water, on a tenure strictly analogous to that of English Commons. We have the struggle between the Lords and the Commoners, and questions between the Commoners and the landless members of the community, just as we have had in this country. Then we have the growth of English ideas of property in land. We have the overlord, the Zemindar, no longer holding in feudal tenure and receiving customary dues and services, but turned by us into a rent-receiver. We have the struggle of the rent-receiver influenced by our ideas to turn the privileged cultivator into a tenant pure and simple, to appropriate the Commons and to establish absolute property. We have the emancipation of some cultivators as copyholders, the subsidence of others put into rackrented tenants-at-will, and then into labourers. All these stages in the tenure of land we have in the Indian countries where the Zemindar system has prevailed. In other parts of India, where the Government has recognized the rights of and dealt with the Ryots direct, we have the rapid development of small property in land with all the incidents of that form of property with which in many parts of Europe we are familiar.

Then we have another process going on in all properties, small and great. At first the holders of the land are content to pay, as they always have paid to native rulers, the bulk of the rent to the State or to the feudal lord, retaining for themselves only certain dues and perquisites. Under our system the State rent is limited, a portion of it is surrendered to the landholders. From time to time, under the influence of English ideas, that portion left to the holder of the land is increased. In one great province the assessment rendered perpetual in the last century has become so light as to be rather a moderate land tax than a rent. In other provinces a moderate assessment fixed for a very long period becomes a very light assessment before the end of that period, as the country progresses and values increase, the share of the landholder becomes larger every day, he learns to spend that share. When the time for revision of assessment comes he resists any very large or sudden increase, and the Government more and more yields to his demands. Thus gradually property in land in the English sense is established. Tenancy by capitalist farmers under capitalist landlords we have not yet come to in India.

The subject of small cultivation seems to derive a new interest in a new quarter from what is now taking place in regard to the emancipated Africans in the United States of America and elsewhere. I understand that the cultivation which has already made the produce of the American cotton districts almost or quite equal to that before the war, is for the most the cultivation of small independent negro cultivators who raise cotton on a system much the same as that under which the Ryots of India or Metayers of Italy cultivate small farms. There seems to be among the dark races of India and Africa a dislike to regular hired labour, and a preference for independent labour on their own account, which makes them prefer small farming to service, or at all events leads to their doing better work on their own farms. There has been, I think, a disposition to undervalue the agricultural skill of the Indian ryot. And if it should prove that in advanced America, under free institutions, the cultivation of an article of great value and high quality is best carried on by small black farmers, we may well believe that in other countries, too, great results may be obtained by the same system. The settling down to honest labour of the American freedmen is an example full of promise, I hope, for the African race throughout the world. If in all the countries where the state of black freedmen is still uncertain they can be thus settled, a great end will be achieved. And in Africa itself we may hope that in countries now torn by war and slavery a guiding hand may lead the African race to peaceful, prosperous, and happy times.

I merely instance these as cases in which economic problems may be studied in their several stages in countries other than our own. I cannot attempt to pursue these subjects at present.

Proceeding to another branch of economical science, I cannot but think that there has been passing before us of late a very great deal to bring home a view with which I have before on other occasions dealt—that curtly expressed in the homely saying of Walter Scott, that "it is saving rather than getting that is the mother of riches." What an extraordinary economic lesson is read to us in the results of the late French war! True, the French have been politically humbled; true, they have been obliged to pay a war indemnity of crushing magnitude. But what has followed? Misfortune has taught the French a lesson of economy and prudence, triumph taught the Germans a lesson of pride and extravagance. The French have retrieved their losses, they are at this moment commercially the most prosperous people in Europe; they bear without difficulty or distress a taxation far larger than that of any other country in the world, while the Germans, who launched out into extravagance on the strength of the vast sums paid them by the French, are suffering greatly from exhaustion and commercial collapse; their trade is bad, their manufactures are discredited, their people are disheartened. The French are a people of small proprietors and small capitalists; they have not the great masses of accumulated wealth that we have in this country in the hands of great capitalists. But their wealth is more generally distributed among the people, and in their hands it fructifies at least as much in the end; if there are not such high profits, there are not such great spendings. Looking to their capacity of bearing taxation, to the general wellbeing of the people, to the very general possession of small property, it may well be a question whether, after all and in spite of wars and misfortunes, France is not quite as prosperous a country as our own, and quite as happy a country.

This at least is certain, that small people working for themselves, if they do not earn more, at least work more zealously and save more than those who work as the hired labourers of others. I am inclined to think that, treating the matter scientifically, the facts will justify us in reducing it to a law that the small man who works for himself is a thrifty man and saves, while the hired labourer is seldom so saving and prudent. Why is this? I think the explanation is to be found in the habit of forethought and management which is necessarily engendered in the man who, not living on daily wages, is bound in some degree to take thought for the morrow, to calculate his ways and means, to husband his resources for a rainy day, to make forecasts of the provision for himself and his family. To this I attribute it that the small French proprietor, the Irish farmer, the Indian ryot, the Scotch weaver (who is unhappily passing from us) are or were all saving, thrifty men. Where will you find a better class than the old Scotch handloom weaver, the careful, thoughtful, well-educated, independent man, the owner of his own cottage and patch of garden ground, generally prudent, and always ready to hold his own in argument? No doubt modern mechanics make more, but do they accumulate more? The habit of living upon weekly wages diminishes the necessity for forethought. The practice of migrating in search of the best market takes away the desire to own a house and garden. I think it cannot too often be repeated that the great economic question of the day is to reconcile the modern arrangement of capitalist and workmen with sufficient incentives to prudence and economy; that is the problem at the bottom of all plans of cooperation, and of most of the questions connected with Trades' Unions and the like.

Very intimately connected, too, with this question is the great and most difficult subject of pauperism. Poor Indian ryots manage to get on without Poor Laws because they are prudent self-workers. The poor Irish farmers for the most part do the same. In most European countries there are no poor laws. Yet when the people of a country are reduced to the position of labourers poor laws become a necessity. It is found in practice that people living on wages do not make the same provision for themselves and their helpless relations that self-workers do. There has been a strong disposition to meet this tendency by a more severe administration of the poor laws, by driving poor people into the workhouse. I confess that I doubt the efficacy of this system, at any rate I think it may be carried too far, and I was glad to hear Mr Walter of the 'Times' make a manly stand against it in his place in the House of Commons.

It is for us to treat the matter scientifically, and to consider the principles on which poor-relief is founded. The Scotch are a logical people, and they are inclined to take the view that payments to the poor-rates are a kind of insurance. They pay rates when they are well-to-do, and they think they are well entitled to pensions from the rates when they are disabled. Is this view a correct one? or if not, what is the real principle of poor-rates and poor-relief? I think that these are questions which must be answered by those who would take a severe view of the relief system. I am inclined to doubt whether English doctrinaires or central boards can much improve on our careful and prudent system of out-door relief administered by local bodies who thoroughly know their own people.

Even if time permitted I would not venture to deal with great commercial questions in the presence of those who so much better understand them; but there is one question of pressing importance at the present time to which I must allude, the more as it is much connected with the country of which I have a large personal knowledge, India; I mean the silver question. He would be a bold man indeed who would prophecy the value of silver as compared with gold a few years hence I certainly shall not attempt to do so There are countries, China especially, of which we know very little, and I apprehend that the course of the silver-market will very greatly depend on the action of the States of the Latin Union and the United States of America. The disposition of the Government of India seems to be to adopt a waiting policy, and there are not sufficient data to enable any one to pronounce with confidence that this course is wrong. "When in doubt what to do, try how it will answer to do nothing," is a maxim of much value The only plan to which personally I have a little inclined is to put more silver into the rupee, and that would not be safe till we are sure that the change in the relative value of the precious metals is permanent

On one point only in connexion with this subject I should like to say something further. The belief has been expressed, and the Silver Committee has accepted the suggestion, that India is likely to absorb an increased and increasing quantity of silver for currency purposes This I greatly doubt It is said that in many parts of India silver is yet little known for purposes of exchange, most transactions being conducted by the primitive method of barter This I think quite a mistake I have as wide an experience of India as most men, and I know no part of India where traffic is by barter for want or ignorance of coin, except the most remote hill regions of the most savage and unexplored aboriginal tribes which are yet hardly known even geographically The Hindoos are a very old people, they used coin freely when we had none, and they have not forgotten the use of it I should say that the special feature of their transactions is the use of a great deal of coin in cases where we should use notes, cheques, or bills And my impression is the opposite of that which has been suggested. I am inclined to think that as more modern ways are learned less coin will be required, not more When I first went to India very large quantities of coin were hoarded. Every prosperous native prince who managed his finances well according to native ideas hoarded very large sums in coin On the occasion of successions, minorities, and otherwise we ascertained the reality of these hoards The weight and power of a prince or noble was estimated by his store of treasure So in grades below, there was much disposition to put by stores of rupees, and the prosperous peasant, like the Frenchman, either buried rupees in his hut or made them into ornaments for his family—a little capital to be converted into cash when necessity arose Till very recently paper money was wholly unknown, and even yet it is used but to a very minute degree compared with its use in European countries

Now that the country is more opened up every day, that there is more confidence in the British peace, that new channels of enterprise, new wants and ideas are developed, I believe that the habit of hoarding coin diminishes Natives, princes, and nobles spend their money in many new ways. When they accumulate they lend it to the British Government to make railways in their territories, or undertake enterprises of their own, or put it in "Government paper" Smaller people travel by railway, enter into speculations, and utilize their money instead of hoarding it. In one direction, as people become richer the ornaments on their wives and children may become more valuable; but in another direction, there is less hoarding of capital in this form.

In a country where the coin of legal tender is so bulky as silver there is much greater occasion to use paper money freely than where the currency is gold I see not why, as confidence in our notes increases, they may not come to be used ten, or twenty, or fifty times as much as at present, why notes for large sums and silver for smaller sums should not constitute the currency for transactions above those for which copper suffices If the tendency of things should be at all in the direction which I have indicated, it would follow that while we might understand the absorption of a vast amount of silver in the past half century, we might also suppose that the tendency thus to absorb that metal will not continue.

I would ask your permission now to turn for a moment to the subject of education, and to suggest that here of all things there is the amplest room for substituting scientific inquiry and a scientific treatment of that great economic agency for the empirical system hitherto followed. Let us try to work out what are the objects of education, and by what methods they may be best attained. How far and at what stages of the progress of the young human being is education useful as a mental gymnastic, and how far and when as a means of communicating positive knowledge to be retained. As a mental gymnastic, which are the faculties most to be cultivated? and in which, boys or girls, are particular faculties to be drawn out? Can we classify and distinguish the faculties of the mind—distinguish memory from the reasoning power for instance?

I am inclined to think that under the present haphazard system a boy generally gets that mental training which he least wants. The boy with a good memory, who does not need the excessive development of that faculty, does work depending on memory because "he has a turn for it," and his reasoning powers remain dormant for ever. The only boy whose reasoning powers are exercised by Euclid is the rare boy who has a *turn* for that sort of thing, and who does not need such a gymnastic.

Then, when we come to the acquisition of knowledge, can we not distinguish the knowledge to be turned to use in after life? Is there no distinction in the teaching of boys destined for one sphere of life or another? In England, at any rate, do not the chains forged by degrading endowments tie down almost all to the same dull routine? Is the knowledge of the things, the creatures, and the uses of the world put in due proportion to mere empirical learning? I ask all these questions without pretending to answer them, but I do again venture to suggest that education at present, of all things, requires scientific inquiry and scientific treatment. We must even, in dealing with education, go to the bottom of things, and inquire how far qualities are born, and how far they are produced by association and education.

As regards the education and employment of women, is not there great room for scientific inquiry on the question how far the mind of woman differs from that of man? Is there not, in fact, a very considerable mental difference between man and woman, just as there is a considerable bodily difference? Is not woman, to some extent at least, a different creature from man, so that we may in some sort predicate that under certain conditions a man will act in one way and a woman will act in another way, in the same manner (though not in the same degree) as we can predicate that a dog will act in one way and a cat in another? To some degree I am inclined to think that there *is* some natural difference, and that this difference must be taken into account in determining the treatment, the employment, and the functions of women.

It is because I thoroughly sympathize with the desire of so many women of the middle classes to find useful and honourable employment for themselves that I think scientific inquiry into the economic capacities of the creature woman most necessary. If we can once solve that part of the problem, the rest will be comparatively easy. I feel sure that there are many functions, whether they depend on nimbleness of finger, sympathy of heart, or quickness of intellect, for which women are especially fitted, while there are others for which their nature is less fitted and in respect of which they will do well to avoid an unequal rivalry with man.

As education fits a man for his duty in the scheme of economy, so dissipation of various kinds unfits him, and we can hardly exclude from economic science the effect of the abuse of stimulants. I was going to say use and abuse, but I think it may be doubtful whether there is any real use for stimulants at all. In dealing with the matter scientifically, it seems very necessary to inquire how far the appetite for various stimulants is connected with questions of race and climate, and what is the comparative effect of pure stimulants and those which have a narcotic element. It does seem that man when he has the chance will indulge in some luxuries, and that drink cannot be stopped by preaching alone. Perhaps the best hope of a remedy may be to discover the means by which innocuous enjoyment may be afforded to him in consonance with his constitution and tastes. It may be a question fairly open to consideration whether the whisky of the Scotchman is or is not as injurious as the semi-narcotic beer of the Englishman. And then we have the larger question, whether the wholly narcotic opium of the Chinese is worse than or as bad as the alcohol of European countries.

I have been led into the suggestion that these things are very much a matter of race by observation of the very singular way in which in Asia the populations are divided into those who use opium and those who use alcohol, according to race lines, even in countries where the facilities of obtaining the one or the other are precisely similar. In the east of India I found that the consumption of opium in the various districts was just in proportion as a Turanian or Chinese element prevailed in the population. The Aryan races of India never take to opium in a very great degree, except in the case of some of the Sikhs, whose religion prohibits the use of tobacco. Even in the districts where the poppy is almost universally cultivated by the Ryots (and they supply the opium which the Chinese consume), it is a happy fact that the native population does not take to the common use of opium, and there are no greater symptoms of the ill effects of the drug than in districts where it is very rare and dear—far less so than in districts where the cultivation is not permitted, but where there is an Indo-Chinese population. I cannot but think that such race proclivities open up an important field of inquiry.

From so fertile sources of crime as drink and other stimulants one not unnaturally passes to justice and the repression of crime, as essential to economic safety and prosperity. No one who has experienced the vast relief obtained by the change from a crude and undigested state of the law to the use of codes can doubt the immense advantages of codification. It is very greatly to be regretted that so little progress in that direction has been made in this country. Not only would there be the great direct gain, but there would be this enormous advantage, that in a codified shape the laws of the three kingdoms might be assimilated. The very great juridical advantages which we possess in many respects in Scotland would be communicated to the sister kingdoms; and on the other hand we should obtain in Scotland some modern reforms which we need. We should get rid of that shocking anomaly and hindrance to business the necessity of passing in the same legislature separate laws for England and Scotland, only because there is a difference in the legal phraseology and some of the details. I have been much struck by the extreme ignorance which prevails in England regarding our Scotch criminal system. The world is ransacked for examples in regard to such questions, as for instance, the examination of the accused, and yet there is not one well educated man in England in a thousand who knows that in his own island, at his own door, there is a system of criminal procedure most radically different from his own, and, as I venture to think, very worthy of English imitation. Who in England has the least idea of the wholesome Scotch system under which the first inquiry includes the examination of the prisoner before lawyers are permitted to see him, and the record for judicial use of the statements which he makes?

After judicial inquiry comes punishment, and here I am inclined to believe that the civilized world is still very much at fault. I think there is still immense room for scientific discussion on the subject of punishments. There are some great subjects such as sanitation and punishments in respect of which I believe that the experts claim a certainty and a knowledge which has not yet been attained. On the contrary, I think there is still every thing to be gained by inquiry and experiment conducted without prejudice or preconceived conclusions. The mere shutting-up a man in prison without severe treatment is by no means a sufficient deterrent to all natures, and when we seek to be severe, we clash with modern notions of humanity. In one shape, indeed, there seems to be a disposition to revert to a form of torture—that is, by flogging. Yet after a great experience I am myself much convinced that of all forms of corporal punishment flogging is the most uncertain, ineffective, and dangerous. In a light and simple form it is good for juvenile delinquents, whose offences are petty, and whom we would not contaminate by a first imprisonment. And flogging is to some natures a material addition to other punishments. But as soon as we try to carry it beyond this we are placed in this dilemma, that a flogging which is *safe* is an insufficient punishment, a more severe flogging is a sort of lottery; nineteen or ninety-nine men it may not harm, the twentieth or hundredth it will kill. I really believe that it would be safer to cut off a finger or an ear than to attempt to deal with serious offences by flogging only.

It is because I think we do not yet fully understand the science of punishment that I am myself opposed to a too uniform and centralized system of prison management. I thoroughly admit that there is much room for reform in regard to the number of our jails and for improvement in the management of many of them.

Measures to carry out these objects I would gladly see. But, doing so much, I would still both retain in this as in other things the services of the many experienced local magistrates who in this country give so much time and attention to local business, and leave a considerable latitude for some variety of treatment and some facility of experiment in regard to the treatment of criminals.

I do not attempt to go into further detail on these subjects. I am sure that it is better that I should not detain you longer, but should give place to the many interesting papers which will illustrate this Section, and which will, I trust, lead to many important discussions. If the scope of this Section is somewhat wide and perhaps less defined than that of other Sections of the Association which deal with more precise branches of science, it at all events includes a variety of subjects of much practical and immediate interest. If only on the subject of silver currency some light can be shed, great good will be done. That subject will be treated by very able hands, and we shall have the advantage of men of great practical knowledge in discussing it. Other subjects I might mention which will be brought before you in papers of great interest, but they will speak for themselves, and I need not enumerate them here.

Agricultural Statistics. *By* WILLIAM BOTLY.

The author stated that this was a continuation of a previous paper "On Agricultural Statistics and Waste Lands." The antiquity and utility of agricultural statistics in the far East, where they operated as a stimulus to production, gave a knowledge of their resources and averted famine. The elaborate system thereof now adopted in our Australian colonies he considered worthy of imitation by the United Kingdom and all its dependencies, remarking that the entire cost of the Bengal famine (£6,588,000), with the sacrifice of life and its demoralizing effects, might have been prevented had a thoroughly good record of cultivation and its outcome been in operation in India. Of the acreage of Great Britain and Ireland (77,500,000) there were in 1875.—

In corn crops	11,300,030
Roots and green crops	5,057,020
Flax, hops, fallow, and grasses under rotation	7,085,128
ent grasses, exclusive of heath and mountain-land, ed for	30,185,211
Total	77,500,000

Cattle	10,162,787;	increase in three years	444,282
Sheep	33,491,948;	,, ,, ,,	1,245,300
Pigs	3,495,167;	decrease ,, ,,	682,833
Horses	1,875,851;	,, ,, ,,	58,020

The decrease in pigs is accounted for by the high price of barley &c. The import of grain, flour, and meal in the fifty-two weeks ending August 25, 1876, was 116,018,594 cwt. It is estimated that we import about half the corn we consume, and 14 per cent. of our consumption of meat alive or cured. We consume 33,697,783 cwt. of beef, mutton, pork, hams, and bacon. Estimating the population at 33,000,000, each man, woman, and child in the United Kingdom consumes annually 114 lbs. weight of meat, exclusive of poultry, fish, game, and rabbits. With reference to waste lands the author advocates legislative encouragement and security for the outlay of capital, with skill and enterprise in their cultivation, where there was a reasonable prospect of a profitable result. The returns showed an increase of 171,470 acres in cultivation on the preceding year, which, as far as it went, was satisfactory. In conclusion, he observed the present time is favourable to its extension: the people emigrate who are willing to work, sanitation asks and supports it, political economy requires it, philanthropy suggests it, the money-market favours it, the rate of discount being but 2 per cent. When capital and money is a drug at 1 per cent, how can we better employ it than in the increased and improved cultivation of the soil, with the invaluable satisfaction of giving healthy employment to tens of thousands of the people, and permanently increasing the value of our property both individually and nationally?

The Economy of Penalties.

By the Rev. John S. Burt, *Chaplain of Broadmoor Asylum.*

The problem which economy is called upon to solve, stated in its simplest terms, is either to achieve a given result with the least possible expenditure of force, or with a given amount of force to achieve the greatest possible result.

But the problem is seldom presented in a form so simple, either the greatest attainable result is not known, or the available force is not determined, while variations in the force used involve complications with other forces, and therefore also complicated results. Accordingly the problem generally assumes this ulterior form: when the cost of the force used is deducted from the value of the result, to determine the point at which the excess of value is greatest.

This is the form which the problem ultimately assumes in the economy of penalties.

I.

The result to be attained at in the use of penalties is by no means determined.

The general opinion is that penalties ought to be aimed at the complete repression of crime. This opinion was countenanced by Archbishop Whately and by Mr. Bentham, but this opinion is inexact and misleading.

Lawlessness in a population is restrained powerfully by other moral forces antecedent in their action to penalties. Penalties are a *supplemental* force, they are thrown in as "make-weights."

But the incentives to crime which overpower those other antecedent forces counteract also the action of this supplemental force. It is a matter of universal experience that the complete suppression of crime is impossible.

Between what is effected by those antecedent forces and what cannot be effected by this supplemental force there lies an undetermined amount of preventible crime. The prevention of more or less of this preventible crime is the result which ought to be aimed at by penalties.

The amount of preventible crime, and the point at which the crime-rate is affected by an increase or a decrease of penalties, is to be found by a study of what may be called *comparative criminality*. There are great fluctuations in the rate of the commitments to prison among the population generally and in different localities. But these fluctuations do not follow inversely an increase or a decrease in the use of penalties; on the contrary, for more than half a century the amount of crime in its graver forms, and the severity of punishments for them, have gone on decreasing concurrently. This is evidence that heretofore penalties have been used in excess of their proper deterring power.

II.

Of the cost of penalties.

In an economy of penalties there are three subsidiary economies—namely, an economy of pain, an economy of labour, and financial economy.

In this paper the economy of pain is alone treated of. Until the exact point is found at which the amount of crime varies inversely with the increase or decrease of punishment, the problem is to keep crime at a given level with the least possible expenditure of pain.

The infliction of pain in excess of what is necessary is *cruelty*. States cannot lessen the happiness of thousands of the population by severe penalties without incurring heavy costs to the nation. There is a lessening of loyalty, and there is often a revulsion of feeling produced against the Government. There are more than 150,000 commitments to the prisons of England and Wales every year.

There are more than 27,000 persons lying in those prisons constantly. If from arriving at a mistaken result one third or one half of these persons are kept in prisons in excess of what is necessary, the amount of the nation's happiness is lessened to an extent by no means trifling.

In administering the penalty of imprisonment, the economy of pain leads to a conclusion in favour of compressing the penal element into shorter periods of time under a rigorous separate discipline, instead of expanding it over longer periods of time in association.

The longer sentences tell upon the faculties of prisoners, the severe discipline does not.

The popular opinion that a separate discipline cannot be prolonged beyond twelve months is founded on error. The objection shows that the principle of the separate system is not correctly understood. The evidence is conclusive that a separate discipline may be enforced for long terms with perfect safety. Now and then injury to the mind may be produced, but the cases ought to be very rare. Injury both to mind and body will occasionally result from any form of severe punishment, even curative processes sometimes do great injury.

The use of chloroform is occasionally fatal, but this does not overthrow the use of it. If at any hospital the deaths from it were frequent, this would be evidence that it was not administered properly. It is the same with the separate system of prison discipline.

The economy of prison labour and financial economy are necessarily passed over.

If the principles advocated in the former papers were acted upon, one third or one half of the cells in county and borough prisons would be left vacant.

If the principles advanced in this third paper were acted upon, those vacant cells would be filled with prisoners undergoing penal servitude, and the convict prisons would be nearly emptied.

Further investigation of these principles is invited. It is submitted that they are based upon laws of man's moral nature, which govern even governments, and which states cannot contravene with impunity.

On the present extent of Slavery and the Slave Trade, with a reference to the Progress of Abolition since the close of the American War. *By the* Rev. AARON BUSACOTT.

Slavery now prevailed in Turkey, Egypt, Persia, Tunis, Morocco, Madagascar, Portugal, Spain, Brazil, Affghanistan, and in the dominions of the Seyyid of Zanzibar, and amongst the different tribes of East and Central Africa. Every continent shared in this great crime. In Turkey it was a vast national institution, degrading the dignity of labour, demoralizing domestic relations, and paralyzing the influences of modern civilization. Portugal had the will but not the power to abolish slavery throughout her territories. From 6000 to 10,000 slaves were annually conveyed from the Portuguese coasts of Mozambique to Madagascar. Spain stood alone among the nations of Europe in resolutely maintaining slavery in Cuba. At the lowest estimate it was computed that 70,000 Africans yearly crossed the sea into slavery, and, accepting Dr Livingstone's estimate of the numbers massacred by slave-hunters and perishing on the route to the sea-coast, it was computed that not less than 500,000 were annually sacrificed. The author questioned the efficacy of having treaties for the suppression of slavery, when these were only meant to worry petty Arabs or African chiefs, or the Seyyid of Zanzibar, while other and stronger nations were left to do what they wished. He then pointed out that at the close of the American war 4,000,000 of slaves were set free, and he was glad to say that America at this moment was more severe against complicity in slavery than even English law. And now that America had lent her influence on the side of the slave, he thought there would be no difficulty in abolishing slavery. Portugal had decreed that the slaves in some of her islands should be free, but it was questionable whether the decree was in any measure operative. The Queen of Madagascar in 1874 issued a proclamation granting freedom to all slaves imported since June 1865 (the date of the treaty with Great Britain, America, and France);

but there was no evidence that one slave had been freed through that proclamation. Even so late as last year Arab merchants openly exposed slaves for sale in the capital, and no attempt had yet been made to give freedom to the masses of slaves who were natives of Madagascar. After referring to the exertions made by Dr. Kirk, through whom the Sultan of Zanzibar had been brought to make the treaty with England, he said that, according to Lord Derby, the Foreign Office was in communication with the Turkish and Egyptian Governments with a view to the suppression of the slave trade. Thus far has the slave trade been abolished, but the progress of this movement depended entirely upon a strong public opinion. Circumstances were propitious and an earnest effort might now realize all the sacred conditions of British freedom.

On some Special Evils of the Scottish Poor Law. By ALEX. M'NEEL CAIRD.

The author, after referring to the position of the poor people before the disruption, and the fact that in some measure it led to the passing of the Poor Law Act of 1845, said that in Scotland the parish minister and five of his elders were entitled to life-seats at the Parochial Board for managing the poor, while in fewer than one in seven of the whole parishes an equal number of members were permitted to be elected by the ratepayers. There were 326 parishes out of 811 in which the elected members were restricted by the Board of Supervision to a third of those entitled to seats by reason of ecclesiastical office. There were not a few parishes in which only one member was permitted to be elected. Thus a perilous system had grown up of men who contributed little, having the power of spending the money of ratepayers, who had no voice in their appointment and no power to remove them. The constant vigilance necessary to keep pauperism within bounds was not likely to find a place under such a system. Then the advance of expenditure for the poor in Scotland was found in 1847 to be £433,915, and in 1875 £794,910. In England in 1847, the expenditure was £5,298,787, and in 1874, the latest report, it was £7,664,957, while in Ireland, in 1852 (the earliest report he could get), the sum expended was £884,200, while in 1875 it was only £771,553. In Ireland there had been a reduction instead of a growth in the total cost, even including able-bodied, where the population was only five and a half millions, whereas in Scotland the population was only three millions, and the able-bodied had no claim on the rates. That was explained by the known excess to which outdoor relief was carried on in Scotland under ecclesiastical managers. Of 176,787 receiving relief in 1874, only 7752 were in the poorhouse, while in England only one in five of the poor were put on indoor relief, and in Ireland forty-four were in the workhouse for every thirty who got outdoor relief. The independence which formerly characterized the Scottish peasantry had been undermined and destroyed through the facility with which outdoor relief had been given. An illustration of the lax management was to be found in the extent to which loose women of the parish—unmarried women with children—received stipends from the poor-rates, enabling them to live manifestly to their neighbours in greater ease than others of their rank. In the Stewartry of Kirkcudbright there were found on the rolls eighty-seven dissolute women having 207 children, of whom only three women having eight children were sent to the poorhouse. One parish in that county stood among the highest in Europe for bastardy. In January 1875 there were in the southern district of Scotland alone 741 women with 1473 illegitimate children receiving parish relief, and in another district, in May 1875, there were on the outdoor roll 880 cases of single women with illegitimate children. Could it be wondered, therefore, that under such a system, patronized by the Church and its ministers—undesignedly no doubt, but very effectually—the growth of immorality in Scotland should have become so appalling. Did anybody believe that if the management were substantially in the hands of Christian men, elected by those who provided the funds, that such a system could live for three months?

Another evil was the area for rating and settlement. That in Scotland was limited to parishes. In England there were only 647 of such areas, while in Scotland there were 804. In England the population to each area was 35,972, while in

Scotland it was only 4280, and London, with a population equal to Scotland, had only thirty. Nearly one in three of these areas in Scotland had fewer than 1000 inhabitants, and every tenth parish fewer than 500. That caused a great inequality of rating between neighbouring parishes, and a multitude of petty administrations with limited views and increased expenses, and continual interparochial conflicts. As an instance of that, he mentioned that in the Barony parish of Glasgow alone there were commonly between 2000 and 3000 undetermined cases of settlement. Again, the law of settlement was adverse to freedom of liberty, and the effect of it was that a man whose settlement was in a small parish was practically limited to the inhabitants of that parish to find customers for his labour. It operated by creating a fictitious interest, in every land- or house-owner, farmer, and ratepayer feeling it their duty to prevent a man being in their parish long enough to obtain a settlement there. The field for a labouring man was therefore physically limited to narrow bounds round the place where he lived, and any arrangement which artificially increased his difficulty in obtaining a house in another district, where he could have steadier work and better wages, was a source of oppression to him. The law of settlement in narrow areas had led to the pulling down of houses and restriction of the accommodation of labourers in county parishes in Scotland, and one result of that was that nearly one third of the whole people of Scotland lived in houses of one room. That was a fact which required to be enforced on the Legislature, in order that wider bounds of settlement might be adopted, as had been done eleven years ago in England.

On the part in the Operation of Capital due to Fixed or Limited Amounts invested in Trade. *By* HYDE CLARKE, *F.S.S.*

The author stated that it was popularly considered that capital in its excess or in its deficiency was uniform in its influence in all branches of commerce, and he called attention to branches of trades wherein the amount of capital indicated could not practically be increased. A ready-money tradesman, as a baker, might be quoted as an example, and the total of such operations was large. In England, France, and Germany there were a number of persons engaged in such trades, the savings of which in times of prosperity went to form a fund for the larger operations of commerce, and the disturbance of which aggravated the severity of a period of pressure.

On recent attempts at Patent Legislation. *By* ST. JOHN V. DAY, *C.E. &c.*

The author holds that the Lord Chancellor's Bill of 1876 is entirely contrary to what is wanted for the maintenance of an efficient Patent Law; he points out the insufficiency of the numbers of examiners for which the Bill provides. Examination can be and ought to be effectually carried out.

The paper contains statistics for the requirements and practice advocated, shows on what grounds it is desirable to maintain the existing practice of granting provisional protection upon the filing of a provisional specification; the practice of preparing abridgements is unnecessary, and serves no practical end, as in all cases it is essential to refer to the complete specifications themselves.

The author also discusses the clause of the Bill dealing with what the examiners are to report upon, compulsory licenses, &c.

On the Importance of extending the British Gold Standard, with subordinate Silver Coins, to India as a remedy for the inconvenience in India of a rapid Depreciation of Silver. *By* W. NEILSON HANCOCK, *LL.D.*

It was obvious to those who had read the report of the Committee on the Depreciation of Silver that the British currency occupied an exceptionally satisfactory position for meeting the great fluctuation in value which silver was undergoing. In India, under the government of the East-India Company, the primitive arrangement of a silver standard was allowed to remain; and this unsatisfactory state of matters continued till 1837, when, although a new rupee was established, the use of silver as a standard was left unchanged. The result has been that the depreciation of silver has produced a most serious disturbance in the exchanges between this country and India, and has disturbed trade and monetary transactions in India generally. One of the causes of disturbance was the discovery of the fertile silver-mines in California; and he regretted to say that there was no guarantee against a further and still more disturbing fall in the value of silver, like what took place in the sixteenth century after the discovery of the silver-mines of Potosi. Had the assimilation of the Indian and British currencies taken place in 1816 or 1833 no difficulty would have arisen any more than it had done in Canada or Australia. He did not think that the change of the standard from silver to gold would involve any change in the mode of keeping accounts in rupees. All that was required was to fix the proportion at which a sovereign would be a legal tender. As to the desirability of such a change he thought there could be no doubt, and had the change been made when the value of the rupee was two shillings it would have been easy, as a sovereign would then have been exactly ten rupees. To remedy the evil, the author concluded by expressing a desire that a reformation of the coinage and an assimilation of the currency between this country and India should take place during the reign of Her Majesty, as in that way the sovereignty of the Queen would, in the circulation of British rupees and British sovereigns, marked with their fixed proportion of rupees, be associated in the mind of every native of India with the lasting benefit conferred on himself and his country.

On Savings' Banks as a State Function developed by Charity Organization.

By W. Neilson Hancock, *LL.D.*

The results submitted to the Section were:—That now the perfectly safe places for the savings of the poor are provided by the State in such numbers, and for such long hours, and under such convenient arrangements by the Post-Office Savings' Banks, the object for which charitable Savings' Banks were established has been fulfilled, and these institutions have become unnecessary and are a waste of charitable effect.

That the State should withdraw its connexion with them, as the State has only imperfect and divided control, as the limitation of liability of the charitable promoters makes the security imperfect, and as it is bad teaching for the poor to offer them a bounty at the public expense to invest their savings in less perfect security than the Post-Office Savings' Banks.

That the voluntary closing of charitable Savings' Banks is going on too slowly, owing to the too limited provision for the compensation of the paid officers.

That the State would save £140,000 a year immediately, and as the paid officers died or retired would save £280,000 if the system of official audit in Ireland were extended to England and Scotland, and all the Trustee Banks and officers, as soon as the audit was completed, were taken over by the State.

That the services of the charitable promoters and honorary officers in instituting the general system of Savings' Banks for the poor, which the State has been so long connected with, and the great profit to the State of immediate and complete conversion of charitable Savings' Banks into Post-Office Savings' Banks, makes it a case where complete security of service or compensation to the officers would not only be morally just, but economically advantageous to the State.

On the Memorial of Eminent Scientific Gentlemen in Favour of a Permanent Scientific Museum.

By J. Heywood, *F.R.S.*

The Results of Five Years of Compulsory Education.
By WILLIAM JACK, *LL.D.*

In this paper the author did not propose to discuss the question whether the quality of elementary education in this country has improved or deteriorated in consequence of the introduction of compulsion Few inquiries would be more difficult There is no absolute standard of quality. He used the word results for two things which can be measured in figures —

(1) The change in the number of children attending efficient elementary schools.
(2) *The change, if any, in the regularity of attendance at school*

In the English Education Act of 1870 the Government, for the first time, sanctioned the principle that wherever the school board of a locality believes that children ought to be compelled to attend school, parents *may* be compelled to send them under penalty of fine or imprisonment, subject to such bye-laws as the school board may enact.

Since that time school boards representing a population of nearly 12½ millions of people in England and Wales have passed and worked compulsory bye-laws Compulsion is now adopted by forty-six per cent of the whole population of England and Wales, and by eighty-two per cent of the borough population

In the new Education Act of 1876 England has adopted the principle of universal compulsion, creating a school attendance committee where there is no school board, and enjoining that committee or the school board of the locality to make and enforce bye-laws and otherwise carry out the provisions of the Act

They are briefly these —

1st. It is declared to be the duty of every parent to see to the elementary education of his child above five and below fourteen.

2nd No employer is permitted to employ

(*a*) any child under ten years of age, with certain (no doubt considerable) permitted exceptions, or

(*b*) any child over ten and up to fourteen

without a certificate either of education or of previous attendance of a due amount.

These provisions will come into force fully in 1881

After giving the general results for the three countries the writer proposed to look somewhat more in detail to the results of the application of compulsion in the large cities, which are types of 82 per cent of the borough population of England The Act of 1870 decreed a school board for London The first step which the board took was to discover the actual school supply in the metropolis, and to make a reasonable estimate of what was wanted. The Government theory was, that accomodation ought to be provided for one in six of the population After making allowances for the middle and upper classes, and for the necessary absences, the School Board of London decided that a supply for one in eight of the population was enough to provide for *elementary* schooling in its district Accordingly it was necessary to have accommodation for 420,000 children, the population in 1871 being approximately 3,356,000 The Board found schools existing in 1870, or erected or projected between that and 1873, for 308,000, so that their first duty was to build for 112,000 more children Many of the existing schools were inefficient, they had to work gradually towards the remodelling or uprooting of these inefficient schools; they had to alter the habit of irregular attendance. Between the spring of 1871 and the Michaelmas of 1873, two and a half years, they had increased the average attendance by 60,000 At midsummer, 1876, the average attendance had risen to 305,749, an increase of 131,448 over the spring of 1871, when it was 174,301. Thus in five years the average attendance on efficient schools has risen by seventy-five per cent in the metropolis, against the Irish eight per cent. in five years Besides this there were 42,000 in non-efficient schools, which is 12,000 fewer than in the previous year There were 87,000 who ought to have been at school, but who were absent from various causes at Midsummer 1876. This official estimate of deficiency is founded on the theory that 575,000 children between three and thirteen require elementary teaching—say one in six of the population But the School Board of London do not think it necessary to provide school accommodation for more than 440,000 —say one in eight, and in fact they have provided, up to the end of 1876, for

420,000, which was their original estimate of existing deficiency. They have only to provide efficient schools for the children representing the increase of population since 1871.

The change wrought since the foundation of the School-Board system is thus enormous. Considering the number of untrained children drawn for the first time within the School-Board net the regularity of attendance secured is also very remarkable. It was 75 per cent. of the roll in Midsummer, 74½ per cent. at Christmas, 1875, 76½ per cent. at Midsummer, 1876—rather better than that in Scotland; and these results are to be compared with the 67 per cent. of Ireland, where there is no compulsion, and of all England, where it is only partial.

Of the 87,000 not attending school in the metropolis I must add that 65,000 are under five, an age when we in Scotland scarcely think of sending children to school at all. The infant-school system is, it is well known, much more developed in south than in north Britain.

For the sake of simplicity I have neglected the varying increases of population in the large towns. To take it into account would introduce no material change in the comparative figures, and very little change of any kind.

It remains for us to look at the *dark side* of compulsion. In London two preliminary notices precede the parent's summons before a magistrate for neglect of his children. These warnings generally have the effect desired. Thus there were 35,000 A notices in last half-year, which brought 13,000 to school, or made them more regular; then there were 23,000 B notices; these were followed by 3900 summonses and by about 3400 fines. At that time in London 150 people were summoned and 130 people were fined every week for neglecting the education of their children. The cost of this machinery for the year is £24,000, being 1*s.* 7*d.* per head per annum on the *average* attendance secured. But the cost, heavy though it is, seems to me scarcely worth counting compared with the feeling amongst the poor which I should expect these prosecutions to create. There is no sign, however, that the efficiency of the present compulsory action is diminishing. The addition to the attendance in the half-year ending Midsummer, 1875, was 17,600. In the half-year ending Christmas, 1875, it was only 1400. But the winter was an exceptionally severe one, and the increase in the half-year ending Midsummer, 1876, has again risen to 17,252.

Figures and percentages are apt to leave rather a vague and shadowy impression; and it may help to realize the difficulty as well as the extent of the problem practically presented to school-board officers if I take four instances at random from the report of the London School Board. They seem to me to throw a vivid light on the infinite variety of domestic and social entanglements in which the enforcement of compulsion inevitably involves us.

"Richard Rust was summoned for Richard, nine. The lad is a very bad one, and was rapidly going to ruin. The father having arranged with some friends in the country to take charge of him in the future, the summons was withdrawn upon payment of costs."

"Tomlin. In this case, notwithstanding that fines were imposed, and a warrant applied for and granted for the apprehension of the defendant, no good result ensued, as the warrant officer was unable to apprehend the father, who worked in the country, and seldom or never returned home except on Sundays. Application was made to the magistrate for a summons against the wife, on the ground that she had the 'actual custody.' This was granted; but she removed, and the visitor has been unable to ascertain her address. She probably went into the country."

"Richard Raymond was summoned at Lambeth police-court for neglecting to cause his son William to attend school. The father stated that the boy had been refused admission on account of an impediment in his speech. In order that inquiries might be made Mr. Ellison adjourned the case for one week, when the statement of the father being proved false a fine of 2*s.* and costs was inflicted."

"Henry Warner, summoned for his son, aged ten, pleaded that it was no fault of his, that his wife was master of the situation, and would not let the lad attend school. Case was adjourned for inquiry, which resulted in establishing the fact that the defendant was certainly not the master of his household; but the magistrate said he ought to be, and fined him."

A family like Rust's shifts its residence out of London The case drops out of the cognizance of those who have long been watching it, and new officers have to take it up from the very beginning Tomlin's father is never at home except on Sundays; and when the school board officer summons the mother, who has "the actual custody," Mrs. Tomlin slips through his fingers like an eel Raymond's father pretends that he has an impediment, and that schools won't take him in. Poor Warner has a wife who won't let the lad attend school, and won't let Warner send him there. There are forty cases for every one of these every week, two thousand times as many of such stories are told annually before the police-courts of London, every one of them with some ingenious variation of pretended excuse, or some miserable and perplexing real difficulty

The statistics of Liverpool are as follow:—The cost of compulsion is about 2s per child *on the roll* (about 3s per child in average attendance), which is about twice what it is in London The increase in the average attendance on public elementary schools in five years is from 33,827 to 41,192, being 21 per cent, as against the 8 per cent. of Ireland or the 75 per cent of London The average attendance has fallen from 70 per cent to 64 per cent of the number on the roll, which is very significant of the class of children brought in by the compulsory clauses Besides the public schools the authorities of Liverpool estimate that there were 10,058 on the roll of all other elementary schools in 1871, and 14,300 of all others in 1875. Liverpool has advanced, but very much more slowly than London It started very much better than London did, and had far less leeway to make up It is difficult precisely to compare its present educational position with that of London, because the non-public schools occupy much more of the ground in proportion than in the metropolis. Its population was 493,000 in 1871, and there were 14,000 seamen belonging to the port. So far as school attendance goes there is probably little now to choose between the two cities.

In Liverpool great attention is paid to the working of compulsory bye-laws. In the year ending October 1, 1876, 6182 notices were issued to parents, and 1817 prosecutions took place in consequence This would correspond to about 12,000 in London, the rate there being 8000 Before the parent is prosecuted parents are brought by the notices to meet a member of the board and the superintendent of visitors, and such meetings are held two or three times a week For instance, the author is told, "In one small district, having about 2000 children, the parents of 355 were brought before a member of the board, and the present result is that 124 are regulars, 11 are delicate, 10 have removed, 6 are over age, 1 has been exempt, and there are 203 who are still irregular, 24 of these have been summoned more than once. Those from the 203 who are still irregular who have not been summoned are not considered irregular enough for a summons."

The statistics of Manchester are somewhat similar to those of Liverpool. The Manchester attendance returns were first collected by the board in December, 1871. At that date the average attendance was 26,328, and the number on the roll was 39,240. The last quarterly returns for the quarter ending June, 1876, showed 32,220 children in average and 50,461 in roll attendance. Thus in 4½ years the average attendance has risen 22½ per cent, or 5 per cent per annum. The population of Manchester has remained practically stationary during the time, so that the same extent of increase was not to be expected as in the case, for instance, of Glasgow and of London But the general effect on the results of making the allowance would nowhere be of very great importance.

The regularity of attendance may be measured as usual by the proportion which the average bears to the roll attendance It was 67 per cent. in Manchester before compulsion, it is now 64 per cent; and the change signifies that a new class, whose attendance it is unusually difficult to secure or to make regular, has been brought into school. Attendance in Manchester has not fallen much under the pressure of the compulsory law, but it was not higher before, and it is a little lower now than the average for all England and for Ireland.

The compulsory powers of the School Board are extensively used in Manchester. The clerk of the Board tells me that the recent average is seventy or eighty cases brought before the magistrate per week. The pressure is exercised on two grounds—non-attendance and irregular attendance; and the board at present aims to constrain children to give at least 80 per cent. of possible attendances The population of Manchester is 351,000, so that seventy per week—say 3500 per year—represents one prosecution for every hundred persons But this rate is only the existing or recent rate In the whole of 1875 there were only 1039 prosecutions—say 20 per week, or 1 in 340 of the population The author supposes that the increased activity of prosecution is largely due to the rise in the increased number of attendances, from 50 to 80 per cent, required under recent bye-laws, in the last week of which he was told the prosecutions amounted to as many as 130, which is pretty much the same as for the ten times more populous city of London. He does not know the expense of school-board prosecutions in Manchester. Both in that city and in Liverpool the attendance seems to have become slightly less regular under compulsion.

In Birmingham the results are very remarkable The city was the head-quarters of the Education League, and that powerful and intelligent organization influenced the School Board *Noblesse oblige*. The first Birmingham board felt itself bound to show what educational zeal could do In December 1871 the average attendance in public elementary schools was 16,203 Compulsion was not resorted to till May 1872. Then and since then the average has been —

December	1871	16,203
May	1872	20,028
„	1873	28,035
„	1874	30,330
„	1875	34,718
„	1876	38,817

Thus in 4½ years the apparent increase in Birmingham has been 138 per cent When account is taken of half-timers, according to the modes of computation of the department, the increase in these 4½ years is the prodigious one of 150 per cent. In addition to this the proportion of average attendance to the roll attendance has risen from 62 to 70 per cent. These magnificent results make the record of the first two school boards of Birmingham memorable in the educational annals of England. They have not been obtained, however, without great exertions and severe pressure Since May 1872 prosecution has been resorted to in 7515 cases, an average of 1900 annually. At that rate the annual average for London with its 306,000 of attendance should be 17,000 instead of 8000. Birmingham manages compulsion cheaply. Prosecutions used to cost them £1000 annually, they now cost, under a system of specially reduced fees, only £300. But the chief expense of compulsion in London, and probably everywhere, is due to the staff of visitors The mere legal expenses of compulsion in London were under £300 in the half-year ending Midsummer, 1876.

The compulsory action taken in London, Birmingham, Manchester, and Liverpool is very stringent. In London there is one prosecution annually for every 450 of the population; in Birmingham about one for every 200; in Manchester about one for every 100 at present, and about one for every 340 in 1875 To the author it appears doubtful whether the poorer classes will long endure such a pressure with patience. As the conviction of the necessity of school attendance and the habit of obedience to the law deepens in the masses of the people we may hope, doubtless, that the same results, or others even more satisfactory, may be obtained at a far lower cost of legal process, with all the hardships and harassments which it involves. But it is difficult to believe that so much pressure is necessary.

In these respects the procedure and experience of Glasgow are in remarkable contrast with that of England. The authorities started two years later than in England; and as new schools have often to be built before children can be driven to school, the first years of compulsory action are always the least effective. The results are these. In inspected schools, and not inspected efficient schools charging the same as board schools, there were

30,103	in average attendance	in	1873
36,568	„	„	1874
42,675	„	„	1875

The rise in two years has thus been 12,572, or 42 per cent., a rate almost as remarkable as that of Birmingham. The percentage of average attendance to roll attendance amounts to

79 per cent in 1873
76 „ „ 1874
78 „ „ 1875

which is still more remarkable. The latest results (October 9) are that Glasgow has managed to raise her average attendance to 84 per cent of the numbers on the roll. Some not inspected efficient schools are included in these estimates, but they are a small fraction of the whole, and their exclusion would not materially alter the proportions of increase. They account for about 3000 children. Setting them aside, indeed, we should have an increase of 50 per cent in the two years in the inspected schools, which is nearly quite equal to that of Birmingham.

The remarkable part of the case of Glasgow is the manner in which the compulsory clauses have been worked. The Glasgow secret is very simple. The board goes down among the defaulting parents, holding frequent meetings in their own localities, to hear the stories of the poor and to persuade them for their own and their children's good. They try every thing before they prosecute. They distribute fly-leaves copiously, narrating the facts, so as to make every actual prosecution go as far as possible in persuading other people. Gentleness would be useless without firmness, and the Glasgow board has not worn its sword of justice altogether in vain, but it has shrunk from prosecutions with an energy and a success which, now that compulsion is to be universal, it is hoped we may see widely imitated. In some rural districts, and perhaps with sensible women for compulsory officers, prosecutions ought to be almost unnecessary. The fact that the law is in the background ought there, at least, to be generally sufficient.

The name of the convener of the Glasgow School-Board School Attendance Committee will long be held in honour for a work unique in its character and in its successful result. In the three years of his reign the School Attendance Committee has dealt with 20,515, less by removals 2819, and exemptions 1684—say 16,000 defaulting parents. Of these, 8000 sent children to school after a remonstrance and personal warning by visit of the officers, 5800 more went to school after notice sent to them warning them of the possibility of prosecution following that notice. The members of the school board themselves met with the defaulting parents on eighteen separate occasions, and 1400 children of the balance of nearly 2200 were sent to school in consequence. *Only 51 have been prosecuted during the three years of the action of the Board.* Every thing is done to avoid prosecutions, it is only when every thing else fails that they are resorted to. The ratepayers' money is saved, the goodwill and the consciences of the people are enlisted in education, the work of future boards is made infinitely easier, and attendance more regular than elsewhere has been secured. No part of the labour of the Glasgow board has been more profitable than the eighteen meetings held with defaulting parents, in different parts of the city where the people live, between February 1874 and January 1876. There were 1834 parents summoned to meet the board, representing 2200 children. All but 250 of the parents answered. The board divided itself into fragments, each sitting separately, and in the whole of a long day getting through about one hundred cases each. Mr Mitchell has shown how to meet the greatest difficulty of the compulsory system. His is a kindly and patriarchal government. Parents are, so far, reasonable creatures, and an ounce of gentle but firm persuasion seems to go as far with most of them as a pound of punishment. Even if, on a review of the whole circumstances, it might seem desirable, it might in some cases be difficult to go back on the decided steps which have been taken, and these steps, it must be remembered, have been fairly effectual. In London and Birmingham the results obtained are undoubtedly satisfactory, and in Liverpool and Manchester they are considerable. The author does not pretend for a moment to criticise the action of men to whose admirable labours this country and these great communities are deeply indebted. He has no wish to make out percentages of credit for the different communities and school boards. If he did he should certainly have to take account of an infinitude of circumstances which he has neglected here. He is dealing only with actual results. But nobody will doubt that persuasion, with punishment in the background, is a better way than punishment if only it be a possible way; and Mr Mitchell has shown that it is possible in Glasgow, whatever may be the truth with regard to other great cities which have acted more strictly Half the country comes now, for the first time, under compulsory laws, and we may hope at least to disseminate education as widely as in Glasgow by the same wise and benevolent effort among a willing people

Compulsion costs far less in proportion in Glasgow than in Liverpool—about 1*s* 2*d* per head of the average attendance, instead of 1*s* 0*d* in London and 3*s*. in Liverpool The amount, which is £2400 instead of £5700 per annum for Liverpool, is considerable, but it is less than that incurred by more stringent action The process has so far been equally effectual, and it cannot fail to leave the poorer classes in favour of, whereas the other mode of action may, one fears, leave them hostile to, education The author in conclusion said —

There are few presentations of statistics to which some objection may not be taken, and the educational statistics of the large towns under school boards, and of the country so far as it is under the official cognizance of the Privy Council, can form no exception Some private adventure schools for the classes that need elementary education still survive, and a few of them may be efficient It would scarcely affect my figures, the main value of which is comparative, if I attempted to estimate these additional elements in the problem on the inadequate data which are alone accessible If we confine ourselves to the broad general conclusions which lie on the surface of the figures I have given, I think we cannot go very far wrong. I throw together the results for the five cities —

	Cost of compulsion per child in average attendance	Present rate of cases prosecuted annually of population	Annual increase under compulsion in children taught	Change under compulsion in regularity of attendance
London	1*s* 7*d*	1 in 450	15	From to 76 per cent.
Liverpool	3*s*. 0*d*	1 in 270	4	„ 70 to 64 „
Manchester.		1 in 100	5	„ 67 to 64 „
Birmingham		1 in 200	31	„ 62 to 70 „
Glasgow	1*s* 2*d*.	1 in 20,000	25	„ to 78 „

I have not taken into account the educational position of the great towns at the beginning of the compulsory era, and that is undoubtedly an element (and a considerable element) in the problem. But there is none of them in which there was not room for very great advances, and in most of them ample room is still left for increasing both the amount and the regularity of attendance. The population of Manchester, for instance, is 8000 more than that of Birmingham; but the average attendance there is only 32,000, against 30,000 in Birmingham The London average attendance would need to be something like 380,000 instead of 300,000 to reach the Birmingham level. The Glasgow attendance still remains very far below the point which it may be expected to reach I have contented myself with recording the rate of advance from a position far behind that which the great cities have now reached to one distinctly behind that to which they will probably soon attain

There is another point to which I have adverted already The Scotch act does not, like the English act, suggest and authorize the making of bye-laws requiring so many attendances out of the whole number possible The sheriff of Lanarkshire might refuse to recognize any standard the Glasgow board inclined to set up. But the bye-laws regulating the amount of attendance with which the English boards will be satisfied are permissive and at their own discretion, and if they choose they may dispense; and Mr. Hughes, a leading member of the Manchester School Board, seems to think that they ought to dispense with such bye-laws. These rules multiply statutory offences according to an arbitrary definition. They create and, as it were, authorize a recognized minimum of attendance. The Birmingham board have no minimum named, and are therefore much in the same position as the Glasgow board. Their bye-laws require perfectly regular attendance, and they enforce them at their discretion Perhaps the Glasgow board and the other Scotch boards could not if they had wished have prosecuted as frequently as their neighbours in England Mr. Mitchell thinks so, and believes that a very great deal of the greater leniency and the smaller amount of prosecution in Scotland is due to the more lenient spirit of the framers of the Scotch act He is most probably right, and one of the main points to which I hope that this discussion may direct the attention of school boards is the policy or impolicy of very numerous and stringent bye-laws. But I must again disclaim any wish to assign credit to individual boards, or to seem to sit in judgment on their conduct

I think that my figures conclusively prove that the best results, both in increased quantity and regularity of attendance, are not necessarily connected with the strictest working of the compulsory law Manchester, which seems at present to be strictest, and Liverpool, which is third on the list, are lowest in both respects. Birmingham, which is second in strictness, is highest in increased quantity as well as in actual amount of education, and third in respect of regularity of attendance, which has risen there in a remarkable degree London, which seems most lenient of the four great English cities, has increased education much more rapidly than Manchester or Liverpool, though it seems to have now reached very much the same level in respect of quantity It has a more regular attendance than either of these cities or than Birmingham Glasgow, which in respect of compulsory action by legal process is almost ludicrously lenient in comparison with the other cities, stands highest in respect of the regularity of attendance obtained, and second in respect of the increased quantity of education Of course neither Glasgow nor any other board can reap where it has not sowed, and the paucity of legal process is no sign that the Glasgow board did not spend an indefinite amount of labour in securing the results it has obtained I am speaking only of the last resort to the fines and penalties of law, and I think I can scarcely be mistaken in saying that my figures almost disprove the theory that the tighter the screw is pressed down in the way of actual punishment the more effective must the pressure become

I do not care to press the inferences that the facts I have collated seem to me to establish any further than these conclusions —

1 That the need of the country for compulsory education was a crying need in 1870

2 That the success of the experiment which has now been tried in Scotland and in nearly half of England justifies the modest advances that have been made by the government in the bill of the present year

3. That compulsion has been carried out in one great city with perfect efficiency, and with a very trifling amount of legal process.

4. That no connexion between stringent *legal* compulsory action and great educational result is indicated by the figures. It is almost needless to say that I do not suppose that a school board can safely leave the matter to take care of itself.

The Valuation of Property in Ireland. *By* HENRY JEPHSON.

An increasing desire has latterly been evinced for the assimilation of the laws of England and Ireland. Amongst those which should be assimilated are the laws on the valuation of property. In England and Scotland the valuation is based upon the rent, in Ireland it is based on the prices of agricultural produce. Very strong reasons can be adduced for the revaluation of Ireland. The present valuation has practically not been revised since it was made, about twenty-five years ago; the value of property has, however, changed considerably, and great inequalities exist as to the incidence of taxation. A revaluation being therefore necessary, it is recommended that the English and Scotch system be adopted, for not alone is that system more correct, but by adopting it the principle of valuation of property would be made similar throughout the United Kingdom. By acting on this recommendation we should remove the inequalities in the incidence of local taxation; we should also remove the necessity for a large amount of separate legislation for Ireland, which is entailed by a different valuation, and we should make another and a great stride towards an object, on many grounds most eminently desirable, namely, the assimilation of the laws of the two countries

On Physical Education and Hygiene in Schools *By* W. Jolly

On the Organization of Original Research. *By* Rev. Dr M'Can

On Spanish Mining. *By* Don Arturo de Marcoartu.

On the Depreciation of Silver and a Gold Standard for India.
By Stephen Mason

The author proposed, as a simple and effectual remedy, the altering of the standard of value from silver to gold The substitution of the one standard for the other might be carried into effect by the following method :—Let the Indian government adopt a gold standard as a measure of value as soon as practicable, and without delay fix a date when all transactions shall be paid or settled upon a sterling basis for all sums exceeding ten rupees This plan did not involve the necessity of altering the currency of India—a very delicate and difficult operation, as Germany has found to her cost The substitution of a gold for a silver currency in India would require at least £100,000,000 of gold, and entail a loss upon the Indian government of not less than £20,000,000 sterling, possibly much more, besides dislocating the whole money markets of the world, and in all probability lead to a great financial crisis in this country. This policy should at once be dismissed as impolitic and unwise.

On the Silver Dilemma. *By* J. Matheson, Junr.

The well-ascertained facts affecting the question were :—1st, that the price of bar silver, which for many years previous to 1873 had been sustained with little fluctuation, the average being almost 60½*d* per oz, had since that period steadily declined (the drop as regarded the present year especially being unequalled), viz from 56*d*. in January to 47*d* in July, 2nd, that the downward movement was influenced by a variety of causes, of which the principal were the increased production of silver, and the falling off or a blank in some sources of demand; and 3rd, that the extra yield was entirely accounted for by the increase of the production of the American silver-mines from £5,750,000 in 1874 to £7,400,000 in 1875, with the prospect of a further increase in the present year.

With respect to the various schemes put forth for a reform of the Indian currency he described as errors the idea of supposing that the value of the rupee could be raised by legislative measures otherwise than locally, temporarily, and with gross injustice towards one section of the community, or that a double standard might be adjusted and sustained with impunity, or that the mercantile public of India could be forced to import gold for the currency purposes of the country, without being the victims of a one-sided policy. If a gold currency were desirable for India the government alone, following the example of Germany, might fittingly provide it.

The general conclusion was that there was nothing in the existing crisis to warrant the demonetization of silver; and further, that the principal silver-valuing countries, even if they desired to do so, were not possessed of such wealth as might render the attempt practicable. The question was essentially fraught with uncertainty. He could not but think, however, that the more thoroughly we grasped it the more clearly did we perceive the all-dominating power of those great natural laws, any interference with which would produce confusion worse confounded, and on the operation of which we might reasonably rely for relief from the present emergency if we would only let them alone.

On Overcrowding in Liverpool. *By* R. W. PITCHER.

On the Educational Value of their Native Language to the Gaelic-speaking Population of Scotland. *By* Rev. W. Ross.

The author stated that his experience, which was fortified by that of the government inspectors, of Sheriff Cleghorn, Sheriff Nicholson, Bishop Eden, and others, was that the effect of banishing the use of Gaelic from the classes in English or Highland schools was that children were taught to read English fluently enough without understanding the meaning of what they read. During the past ten years he had examined ten thousand Highland children, and he was convinced that satisfactory educational results were to be obtained only by pursuing a different method from that of excluding Gaelic translation which had hitherto been followed. To ignore or exclude the native language from the school was to prolong the use of the Gaelic language (a prolongation against which he did not personally object), and to do so at the expense of intelligence, education, and culture. The only way to obtain an intelligent acquaintance with English in a large section of the country was to make use of the native tongue in explaining the meaning of English terms; and the admitted failures in the past were in his opinion to be traced to the irrational method so long and extensively practised.

Sheriff Courts and Relative Judicial Statistics.
By F. RUSSELL, *Sheriff-Substitute of Roxburgh.*

The author gave an historical sketch of the Sheriff Courts, which took their present form after the rebellion of 1745. At present the Sheriffs appointed their own substitutes, and the aggregate salaries of these judges were nearly £40,000 per annum. The jurisdiction of the courts extended to all criminal offences except the four pleas of the Crown; and during the last three years the number of people tried in the Court of Justiciary annually was 507, and in Sheriff Courts 2012, besides what were known as summary trials. After the establishment of the Court of Session in 1532, the jurisdiction of the Sheriffs in civil matters was limited, though still extensive. The average annual number of final judgments during the five years from 1870 to 1874 in the Court of Session was 1280, and in the Sheriff Courts during the same period were—ordinary court 5476, debts recovery court 2550, and small debt court 38,458. The appeals to Sheriffs during the last three years had averaged 527, of which 341 were sustained, 180 received, and 106 mixed.

The Civilization of South-Eastern Africa. *By* JAMES STEPHENSON.

On the Theory and Practice of Accident Insurance by Sea and Land.
By P. M. TAIT.

Commencing by about thirty definitions of the word "accident" according to various authorities (very useful information for insurance companies), the paper treats separately in great detail of ocean accidents, railway accidents, and general accidents.

As to ocean accidents one curious fact was brought out, that these vary with the age of the captains commanding the vessels, there being apparently a certain epoch in the life of a master mariner when danger of disaster is reduced to a minimum. Other things being equal, passengers are safer to sail under a captain of about 50 than under one of an earlier or more advanced age The entire premium to cover increased risk of master mariners is from 30s to 40s per cent per annum, that is to say, if a clergyman or barrister can obtain insurance on his life for £100 at a premium of £4, the premium required to insure a master mariner of the same age would be from £5 10s to £6 This is the ratio all round, but captains of Cunard's and other first-rate lines would of course be insured for less

As to railway accidents the facts were not brought up to the latest dates But it comes out very clearly that the risk to railway officials actually employed on the line is excessive Nearly all railway accidents are remediable, and the chance of disaster could be still vastly reduced by a universal adoption of the block and interlocking system, the use of perfect brakes, and other improvements long ago suggested

The mortality from accidents generally is a very important and interesting department of vital statistics The number of accidents occurring in England and Wales is reproduced from year to year with extraordinary regularity, indicating the operation of a fixed law Excessive division of labour has a tendency to increase accidents by the introduction of new machinery, at first often imperfectly understood The introduction of rinks and bicycles has led to a wholly new class of accidents requiring special medical treatment

Insurance offices charge the same premiums against an unforseen casualty from the ages 15 to 60 But from very recent data wholly reliable it was very clearly shown in the paper that the mortality from accidents increases greatly at the more advanced ages, and that consequently some difference should be made in the premiums applicable to those ages It is not that there are a greater number of accidents at those ages, but that there is less power of rallying from the effects of an accident

The paper concludes with specimen policies of the different companies, showing the risk covered and the general conditions of the accident insurance contract

On the Boarding-out of Pauper Children in England By Wm Tuliack

The author said that the system had been adopted for five years in England, but in consequence of want of information, and an unfounded confusion in the public mind of the system with the obnoxious and wholesale farming out of children with which so many evils and cruelties were associated, it had not made the progress which might have been anticipated He warmly advocated the system, more especially for girls In contrasting it with the workhouse plan, he drew a vivid picture of the evils attending the association of children with adult paupers who were often vicious, and with other children, many of whom had been swept from the streets In the system of district schools he recognized a great improvement, but he did not think it was equal, especially in the case of girls, to a system of boarding them out singly in carefully supervised cottage homes But the district school system was also objectionable on the score of cost A sort of institution mania had taken possession of many minds It seemed to be assumed that both adults and children should be gathered in masses and lodged in palatial abodes at the public expense, and parents were tempted, he believed, to suffer their children to go into these places where they could get an excellent education with all the advantages of a costly middle-class school at the public expense The Scotch people, with proverbial natural shrewdness, had perceived and warded off this danger which was burdening England Poor persons in Scotland were not tempted to throw their children on the rates by providing them with these palatial edifices Whereas many such children in England cost from £20 to £30 per annum, the offspring of destitute Scotch poor were as well or better cared for as a body for £10 each, being trained under careful supervision in healthy and well-selected houses amongst the labouring classes, where they were never subject to the influence of the workhouse, but were gradually and naturally introduced into the wholesome conditions of family and industrial life This wise system of supervised boarding-out was being gradually adopted in England, and it was to be hoped that in a few years it might become the general rule at any rate for pauper girls There were altogether 573 poor-law unions in England, of which 127 had adopted the boarding-out system in greater or less degree for some of their pauper children There were, in addition, forty-seven Welsh unions, of which thirty had adopted the system The number of children boarded out was in England 1500, and in Wales 900 In nearly all the cases where the system had been applied it had been found very successful, and the writer of the paper supplied a large number of extracts from reports from Birmingham, Clifton (Bristol), Chorlton (Manchester), the Cumberland Unions, and the agricultural districts in Kent, showing that where the system was applied children were cared for at the rate of from £10 to £12 a year, that the children boarded out were improved in health, and had been readily drafted off into situations The only cases in which the system had failed in accomplishing these blessed results was where there had been a neglect of supervision He therefore advocated the formation of ladies' visiting committees in connexion with the unions At present the number of district and separate schools was very small as compared with the number of pauper children The erection of many such costly institutes was attended with pecuniary difficulty and was of questionable expediency On the other hand, sound economy and efficient results were combined in the application of the system of boarding-out, especially for children, but the system should be applied in its completeness and entirety, and with frequent oversight by judicious visitors, and provision for the religious and moral education of every child

The Prevention of the Pollution of Rivers *By the* Rev. R Thomson

The Statistics of the Indian Opium Revenue *By the* Rev F S Turner.

The last debate on the Indian Budget in the House of Commons demonstrated the vital importance of the opium revenue, it is therefore important to inquire into the probable stability of this revenue At first sight an inspection of the returns from 1792 to 1872 is highly encouraging During this long term of years we mark an increase, steady on the whole, though with minor fluctuations, from £292,751 to £8,000,000 Not so satisfactory is the increasing *relative* importance of the opium revenue, which from being in 1792 one thirteenth of the land revenue, and one twenty-eighth of the total revenue, has now risen to the serious proportions of more than one third of the land-revenue, and more than one sixth of the total revenue These figures refer to the gross revenue, and have to be slightly diminished for the net revenue Making the necessary deduction, opium has in eighty-three years yielded the total net profit of £184,000,000, which may be taken as a partial set-off against the sum which British rule has cost India during the same period

High authorities have warned us that we ought not to rely upon the continuance of this income, among others, Sir Charles Wingfield, six years ago, in the House of Commons, and this year, Sir George Campbell in the 'Fortnightly Review'

Our lucrative monopoly of the China market is threatened by the competition of the Chinese themselves This competition has been held in check by their own government, which, however, has gradually relaxed its opposition, and now threatens to abandon it altogether The poppy has spread enormously in China since 1863 For the last four years there has been a diminution of our opium revenue, which *may* be the beginning of a continuous decline Some recent items of news from China show that there is still some uncertainty about the direction Chinese policy will take J S Mill has pronounced against interference with the opium trade, but, according to his own principles, an argument may be advanced in defence of the Chinese prohibitory legislation Great difficulties are thrown in the way of this legislation in China by the political action of Great Britain Thus opium may perhaps still continue to bolster up Indian finance until moral laws work out some unexpected, but not undeserved, retribution

MECHANICAL SCIENCE.

Address by Charles W. Merrifield, *F.R.S., President of the Section.*

It is generally most useful and most interesting to intelligent listeners to hear from those who address them that which is the most familiar to the mind of the speaker. Passing by the question of primary education, I propose, therefore, to review briefly our shortcomings in those subjects of instruction which are the necessary preludes to natural, and especially to mechanical, science. I then propose to direct your attention to some points dependent on the crowding of the population, and especially to those consequences of it which are chiefly interesting to the Section of Mechanical S[illegible]

To such an assembly as I see before me it hardly needs that I should say much on the importance of a widespread knowledge, as sound and exact as it can be made, of the nature of all things about us We need this not only as a nation to compete with other nations, but we also need it more and more every day as men The crowded condition of the earth at this day is in the strongest contrast to its state in the early days of our race; and the necessities of our life then and now are in as strong contrast as those two conditions, or as the numbers who lived and live subject to them. Even in the early days there was more knowledge afoot than the thoughtless among us dream of At no stage of man's history was life to be held on easy terms, and to those who in early times neglected the knowledge necessary to take care of themselves and those about them the penalty of their remissness was short and sure It is not less certain now. Equal difficulties and dangers still beset us, and are to be met with in the same way—by acquiring knowledge, and by applying it with industry and judgment. Only the knowledge that we want is greater now than then, and, being a higher development of knowledge, it requires to be more systematically learnt and taught This is an absolute necessity to us if we wish to extend, or even to preserve, the possibility of our maintenance in such masses as are gathered together in Western Europe, and in such towns as London or Glasgow.

Although the possibility of our existence as we are has been the consequence of our ancestors, whether advisedly or not, yet successfully, following the law just indicated, it is one of the concomitants of their success that we have brought up amongst us the weak and foolish, who have received the benefit of the knowledge and industry of others without participating in either sufficiently to understand the conditions which have rendered possible an ignorant, an idle, or a vicious life. Just as the citizen of a country which has been over long at peace does not understand that his safety depends upon the fighting power of himself and of those who will take his part, so there are some in our midst who do not see the danger of ignorance or the waste of idleness. Those among us are perhaps few who do not recognize some disadvantage in ignorance and indolence, but there are, I fear, many who fail to realize the urgency of extirpating both to the uttermost Let me not be misunderstood; I do not suggest that there should be no pause from learning or from exertion; life would not be worth having without its intervals of ease; but the enjoyment of these precious intervals is only to be purchased at the expense of habitual thought and exertion, and, in our present social condition, we cannot safely neglect to afford to all amongst us opportunities of cultivating observation and thought.

These remarks may seem to you something like "slaying the dead" To those engaged in the active work of mechanical industry, ignorance, stupidity, and indolence are the enemy at the gate, with whom there is and can be no truce. But let me ask even you whether you have not among your circle of acquaintance many who think that the erudition of a few and the ignorance of the many is a better state of things than the universal and systematic instruction which, happily for ourselves, our representative assembly has now determined to secure for all amongst us. Let me ask whether there are not some who think the study of history or literature far more important than natural science; some also who think that religious teaching supersedes all other learning. All these doctrines are in my opinion false, and dangerous to society. I do not undervalue either religious teaching or historical knowledge Of the former, this is not the place in which it would become me to speak, even were I its authorized exponent Of the latter it would be almost equally preposterous to speak slightingly No one feels more keenly or practically than I do that the past is the key to the future, and that all our knowledge depends upon experience Not only do I acknowledge this as an abstract truth, but I have myself constantly been driven to historical study before I could attain any real mastery of the work which lay before me in any of my pursuits, even of natural science. Moreover my habits and instincts have a strong bias in that direction, my early education having been classical and legal, and my first actual employment having been in the archæology of painting It is, therefore, with no prejudice against useful scholastic learning that I raise my voice against the misdirection of education. Still less is it with any prejudice against the exactness of the knowledge to be acquired

Let us for a moment reflect upon what marks the difference between what we are pleased to call civilization and barbarism—what distinguishes the Anglo-American from the Red Indian, the Russian from the Tartar, the Western European and his colonial congeners from the races which he is governing or replacing. It is not, or at least assuredly not alone, by muscular superiority, nor is it by mere astuteness, the savage or the half-savage competes with us very favourably in both these respects To emphasize the real difference, let us go a little further back, and ask ourselves why the bear and the tiger are no longer a terror to us, and why we feel secure of the predominance of man, at any rate against the larger and fiercer of the dwellers in the earth, the water, and the air This predominance is due solely to the command which our intellect has given us over the material powers of nature. Physical science has enabled us to set these against the mere unaided strength of brutes Superior and more exact science has enabled the dominant races to bring more of these material forces to bear upon their enemies than the barbarous tribes could array against them This is so universally admitted as a principle that its real application is often forgotten, and there are many who think that our civilization has in it something *sui generis*, some special innate principle which assures us against barbarian attack, instead of regarding it in its proper light, as merely one element of strength which may turn the balance in our favour, provided we are equally, or nearly equally, matched in other respects But history is not wanting in terrible lessons of the utter destruction of civilized communities. Long-continued security and the accumulation of mechanical appliances carry with them and foster the seeds of social decay.

These, perchance, are remote contingencies, although even to nations disaster comes unexpected

More immediate and more obvious risks are these that we may be beaten by other nations, not in a struggle for bare existence, but in industrial competition, and that the crowded population which has to be maintained in these islands, and which former prosperity has accustomed to expensive habits of life, and not to the endurance of scarcity or hardship, may not find the means of exchanging its labour advantageously for the material of its sustenance, or that ignorance of the conditions of health, or inattention to its laws, may expose us to disease. Not all of us, I conjecture, have realized how much more difficult and costly it is to keep in prosperity and health the enormous agglomerations of humanity which Western Europe on the one hand, and China and India on the other present to us, than to feed the scattered populations which occupy the less crowded regions of the globe. I think some of us are now beginning at least to understand that there are material difficulties in keeping any large collection of one group of animated life together, so that each individual shall not intercept or contaminate the sources of nourishment of himself or of others

Now what I wish you to reflect upon is, that these difficulties are material, and are therefore to be met by a thorough and widespread knowledge of natural science. With thin populations, which have more to fear from war and famine than from want of elbowroom, political and historical knowledge in the governing class is more important than exact natural knowledge in the administrative class. As the population thickens, the latter assumes more and more relative importance, and while I do not think political wisdom will ever lose any of its value, I think it only a part of that political wisdom to recognize that in such communities as ours the spread of natural science is of far more immediate urgency than any other secondary study. Whatever else he may know, viewed in the light of modern necessities, a man who is not fairly versed in exact science is only a half-educated man, and if he has substituted literature and history for natural science, he has chosen the less useful alternative.

One of the obstacles to the spread of science, and to our national prosperity, then, I take to be the undue preference given to literary over natural knowledge, and, in particular, the sacrifice of mathematical to classical study in the secondary school. If you ask me why I lay so much stress on mathematical teaching, my answer is, that we need to study natural science exactly and quantitatively, not merely to cram our memory with the qualitative characters of a few phenomena. Now, if we are to count, to measure, to weigh, or otherwise to ascertain quantity, we are really practising arithmetic, geometry, and mechanics. If we can learn these more advantageously than by the ordinary course of mathematical study, we shall simply change the form of that study without evading the thing. But in truth mathematics are too well understood, and on the whole too sensibly taught, to admit of any great subversions. Improvements in detail, and in the selection of the most useful branches for study, there is doubtless room for, and indeed these are being daily made. The chief faults I notice are in teaching algebra too late, and in teaching Euclid (so called) too early. I regard abstract geometry as a foolish study, unless accompanied, and even to a certain extent preceded, by the practice of linear drawing. This is too often neglected. Moreover, I do not consider that what is called Euclid—I use this expression advisedly—is the best possible text-book for abstract geometry. I doubt if Euclid, if we judge him by the best Greek text handed down to us, is suited to our modern requirements. What we actually use is not Euclid, but only isolated portions of his book, freely altered by Robert Simson. In my opinion the omissions and alterations have deprived the book of all lifelike vigour and human interest, and have made it as dull to the mature reader as it necessarily is to the unfortunate boys whose first introduction to geometry it too frequently forms.

Apart from the general fault of giving too low a place to mathematical teaching (a great fault, and one which we are only slowly mending) is our not paying sufficient attention, and sufficiently early attention, to mechanical and geometrical drawing. On this point I need add but little to what was said by Prof. Fleeming Jenkin in his address to this Section at Edinburgh in 1871. That is possibly the point on which we compare least favourably with neighbouring countries. One important remark of his I am anxious to give prominence to, and that is, that descriptive geometry is not what is wanted. I fear, indeed, that many teachers of this subject have failed to realize its true meaning, and confuse it with the theory of geometrical projection, of which it is in truth a development and extension, not a particular application. So far as the preliminary chapters of an elementary work on it are concerned, the confusion is natural and perhaps not very material, for all that relates to the point and straight line is simply plan and elevation, and the plane needs but little more. But the characteristic feature of descriptive geometry is due to the fact that surfaces cannot (with the exception of cylindrical surfaces) be represented by plan and elevation. They are therefore, in this science, *indicated* by a general and systematic method, which, without representing them to the eye, enables us to handle them geometrically, to find their intersections, their tangents, and their shadows, with the same certainty as if we had models before us. So far as points and lines, straight or curved, are concerned, it does not differ from geometrical projection, the difference is, that it deals effectually with planes and curved surfaces, which geometrical projection cannot do. To those who have to deal with curved surfaces it is as important as linear drawing is to the student of plane geometry, because models are practically unprocurable, and conception in three dimensions is not easily got, except through descriptive geometry. But for ordinary school purposes it is a very barren exercise. I state this advisedly, being thoroughly familiar with both its use and abuse. A much more important exercise of geometry, and one more immediately useful, is the geometrical representation of arithmetic, such as we see in diagrams of thrust, pressure, speed, work, temperature, heat, rainfall, and so forth. But I think this will take care of itself provided linear drawing be taught sufficiently early

I should leave my remarks incomplete if I did not make what you may at first sight think a digression, namely, some observations on our practice of teaching languages, especially Latin and Greek But as they do form one side of education, and as we should only be half-educated without them, it is important that they should be effectually and economically taught. And to none is this more important than to those who need to use them, but who can spare little time from their more essential study of natural science I think all who value time will admit, if they allow themselves independent reflection on the subject, that Greek and Latin are taught too much as exercises of grammar and too little as languages It is the same fault as we have had in mathematics, where making boys learn Euclid has been taken to be the same as teaching them geometry Now teaching grammar and "construing" bears to language the same relation that drill does to marching or shooting, or that swimming on a table does to taking the water In all these matters we have learnt that moderate drilling and plenty of work is the best combination, but we have not yet learnt this lesson in reference to the classics. Our ancestors had learnt and practised it They spoke Latin in the schools, and to this the drill-work of grammar and syntax was the proper complement I hope you manage things better in Scotland, but in England it is the rule to spend from six to eight years in learning Latin and Greek, and it is the exception to be able to read either

If we cannot escape the effects of this scholastic tendency to exaggerate the importance of intellectual gymnastics over actual knowledge in classical and geometrical teaching, let us at least do our utmost to prevent its being extended to other languages and to other studies There is a class which is exerting pressure that way

I speak the more fearlessly on this subject, because, having most strongly advocated the extension of pure mathematics, I cannot possibly be mistaken for an objector to exact learning.

Now, returning to the subject of mathematics, I think one cannot fail to be struck with the increasing tendency which they exhibit to pervade all study of natural science I need not ask you whether it is wanted for mechanics In the older books on chemistry, electricity, and so forth, it was quite an unusual thing to meet with an algebraic formula or a geometrical theorem Now, on the contrary, we find that one half of chemistry is pure algebra · organic chemistry, in particular, is nothing but a special branch of algebra coupled with the experimental—I had almost said accidental—fact that its formula are represented by actual combinations. This disguised algebra enters so largely into chemical teaching that I have seen full marks obtained in an elementary examination paper on chemistry by students who really knew nothing of the science, but who did understand algebra well I have recently seen a great deal of scientific work passing through the press, and I have been much struck by the way in which pure mathematics continually present themselves in all branches of knowledge. The reason is not far to seek. We have passed the merely descriptive stages of knowledge in most sciences, and when we come to quantitative study—that is to say, to discuss number, measure, position, and force—we are using mathematics, whether we know it and choose to call it so or not. Moreover, so far as we at present know, ordinary mathematics are the simplest ways of counting and measuring.

I may mention, incidentally, that I think there are evidences that mathematical knowledge is spreading in many directions. Apart from what is doing in the universities and high schools, I have myself an opportunity of observing it elsewhere, as the examiner for elementary pure mathematics for the Science and Art Department. This year, in particular, I am able to say that there has been a very marked improvement in the knowledge of the candidates under examination, and I think the teaching of the science classes under the department is really beginning to tell in this important subject. Compared with the requirements of this country, it is but a small matter, for there are only about 7000 candidates annually, and these candidates come up more than once. Nevertheless it is good so far as it goes, and

I hope to see a great extension of the instruction in this as well as in other directions

Assuming the possession of a certain amount of knowledge, which is now all but universally spread, the only real difficulty of a thin population in a temperate climate is the protection of life and property That assured, they can without difficulty supply their material wants in the way of animal and vegetable food and of clothing A very little and generally a very easy selection ensures a sufficiently pure water supply. Moderate cleanliness will secure sweet air in the houses, and, except in the fens or in certain valleys, there is always pure air out of doors. I do not assert that these conditions always exist in sparsely peopled countries, it is sufficient that they may, and sometimes do, exist.

Insecurity first, and therewith scarcity of food, have been sufficient causes in most countries and in most times to compel aggregation Towns, and even large cities, are quite as much a consequence of barbarism as of civilization The real problem of civilization has been to render life tolerable in such aggregations, and that problem is only yet partially solved We shall see by-and-by that it is now presented to us in a new and very troublesome form It has always been a very difficult question, and the sacrifice of life due to its imperfect solution has been enormous, and is still large

Among the difficulties of town life I reckon chiefly —

1. The insufficient supply of fresh air, whether from overcrowding within the houses, or from narrowness or unwholesomeness of the streets

2 The mere proximity of individuals facilitating the spread of contagious or infectious disease

3. The getting rid of excreta or waste products

4. A wholesome water supply to be provided and kept pure.

Of overcrowding I need not say much here, the circumstances which determine that are the concern of Section F rather than of the Mechanical Section In this country at least it does not fall to the engineer to plan new cities in the wilderness. What he can do is to palliate the effects of overcrowding by supplying the means of ventilation and cleanliness. I do not propose to-day to entangle myself in the great and complex problem of ventilation; yet it is well not to pass one or two points unnoticed.

It is rather difficult to say what pure air is So far as health is concerned, the wind off the sea or the mountain is pure, or as good as pure Whether the east wind be so or not is an open question. I suspect that its unpleasant character is due more to its dryness, and consequently to its chilling effect—an effect quite independent of its temperature—than to any actual contamination. Meat and milk, at any rate, will keep good with an east wind at least as well as with a west wind. However this may be, we are all sensible that when we are to leeward of a large town the wind smells of the town. Not to mention factories and unsavoury trades, one day it has passed over miles of hot roofs and walls, and streets of unclean dust; another day, the rain or the watercarts have converted miles of street into a reeking slough, compared with which a natural fen is a cleanly thing. In any case we know and feel that we are breathing the waste products of human industry and of human life, to the detriment of our vitality, as well as to the offence of our nostrils.

I do not think sufficient attention has been paid to the mischief which may arise from copious watering unaccompanied by careful scavenging. We all know what town mud consists of, its wholesomest element being probably what makes it look the worst, namely, soot. In London there are hundreds of acres of mud and dirt kept almost constantly moist, by rain when there is any, and by watercarts when there is not Now it seems to me that, merely looking at it from a broad general point of view, this is not likely to be healthy; it seems to combine all the conditions necessary to the carrying on of unhealthy putrefactive and vegetative processes on a very extensive scale. I do not pretend to estimate the quantitative effect of this as an element of disease, but I think it would be making a large demand on your faith as well as mine to ask you to doubt its qualitative effect. At any rate, I think we ought to consider very seriously whether mere watering is any proper substitute for careful and complete scavenging, and whether, in fact, we are not spoiling a useful process by an unintelligible application of it—one of the great dangers of improvement.

The second point which I have mentioned—the facilitation of contagious or infectious disease by mere proximity—is obvious enough in its generality. Its details belong to Section D.

The atmosphere is probably a much greater carrier of noxious germs than water; but, as Dr. Tyndall has judiciously remarked, the aerial germs appear to be sometimes in a less forward, and sometimes, perhaps, in a more effete, state of development than those which are met with in water, or which have once taken root upon moist tissues. On the average, therefore, resistance to them is probably easier. However this may be, it is clear that we cannot subject the supply of atmospheric air, which is necessary for our lungs and skin, to the same complete chemical or mechanical treatment as we can, and do, when necessary, our supply of drinking-water. Any attempt at the disinfection of air of doubtful purity must necessarily be of the crudest and most empirical kind. In the present state of our knowledge and resources it can hardly be of interest to the engineer.

The third point affords a remarkable example of what I have just mentioned as the greatest danger of all improvements—their unintelligent use. No one can deny that the watercloset and the sewer are great mechanical improvements; yet they have been great carriers of disease. As applied to the particular problem of getting rid of waste products, especially solid products, I do not think they were any improvement at all on much that we already had. In many towns in Great Britain, where there previously existed a well understood and well carried out scavenging system, I think they have done more in saving trouble than in conducing to health. I think the real key to the problem of getting rid of the nuisance of waste products is to be found in the old aphorism that *dirt is simply matter out of place*. Hence the first step is to take care that such products shall not become waste, and one condition of this is, that they should not be carelessly mixed. The greater part of the sewage difficulty is, I think, simply the result of neglecting this truth. It is especially the case with London sewage. With our water supply, our watercloset system in houses, our drainage of houses, factories, and streets all together, we have accumulated a river of filth, the complex admixture and enormous mass of which have rendered it most difficult and dangerous to control effectually. I think we shall yet be driven to meet the difficulty at its source in the way suggested—by dealing with it in detail, subdividing both from house to house and from kind to kind, and allowing nothing but the mere washings of the streets to get into our sewers at all. So far as the getting rid of waste products is concerned, I believe we must be content to write off the whole cost of our Metropolitan Main Drainage.

There is another undoubted improvement which the legislature has decided upon applying to London, concerning which I feel no small amount of misgiving lest it should be applied without intelligence, and that is, the constant supply of water in place of the intermittent cistern supply. As a mere mechanical convenience it will be a very great improvement, but I foresee two dangers, one of sewage contamination through the waterclosets, the other the waste of an article already becoming scarce. The first is no idle fear. The experience of Croydon and other places has shown that it is possible to make the water supply and the sewage a circulating system, with fever or cholera as its inevitable consequence. It has been bad enough in several places of moderate size, but in London, whether we regard it with reference to the mass of contaminating material, or to the quantity of human life to be affected by it, the risk has a much more serious aspect. I shall be sorry to see the constant supply established in London without taking some effectual security, either by the interposition of cisterns or otherwise, to prevent the possibility of back-draught from the cess to the drinking-water. Without some such precaution, I think the mechanical improvement may be a fatal gift.

I have said that the problem of the crowd, if I may venture so to call that of maintaining purity in the supply of a dense population, is now presenting itself in a new and very difficult form. That is so notably in the matter of water supply; because until now it has generally been possible, by some expenditure in aqueducts and care in the selection of the sources, to obtain a sufficient supply of thoroughly good water, not always perhaps of chemical purity, but at any rate free from any great contamination of animal and especially of human excreta. This possibility threatens to disappear in the United Kingdom generally, and especially so with regard to the manufacturing districts and to the east of England, not only from the mere increase of the population, but much more from the higher cultivation of the land. The moorlands are everywhere being broken up for the plough, fallowing has given place to heavy manuring and to sewage irrigation, both of which are freely applied to pasture as well as to arable land. The population of bullocks and sheep has also increased with the human population. The result is that the rain is contaminated as soon as it reaches the ground. The surface drainage, instead of being water naturally distilled, flowing off clean grass or moss, is the washings of manure. The spring-water, again, is not pure rain-water which has passed through a rock-filter and has taken up some mineral ingredients, but is simply these manure washings more or less completely filtered. In our streams the water derived from both these sources undergoes fresh exposure and cleansing by aquatic vegetation, but at the same time fresh contamination. The mere statement of the problem in this way carries with it, almost axiomatically, the inference that the effective character of filtration is a matter for quantitative investigation, not for assumption as perfect and complete. We know, moreover, that some of these natural filters have been overtasked.

Let us now turn aside to consider what is the work to be done, and what is, so far as we are able to understand it, the work actually done by filtration.

I believe I am right in saying that with the exception of the strong corrosives, which act like weapons rather than as medicaments, no one really knows what poisoning is. We must take it as an expression used to summarize the unknown and possibly inscrutable chain of events of which we only see the primary cause and the ultimate effect. We may perhaps go one step further in respect of the poisonous effect of organic sewage in its unfiltered form. It contains, for one thing, the dead products of organic decay. A grass filter or an earth filter very rapidly renders this part of the sewage innocuous by oxidizing it. Then it contains germs of animal life, some of which, unless intercepted or killed, prey parasitically on the larger mammalia. Thirdly, it contains vegetable germs, closely allied, it would seem, to the moulds and other small fungi; these, finding a resting-place in our bodies, grow and destroy or spoil the cells of which our own growth consists, much in the same way that the yeast fungus modifies the worts of beer, or that the common mould spoils the flavour of a pot of jam. The effect of such spores upon us is called zymotic disease. The first class of impurities is pretty easily dealt with. Probably the means already exist of calculating at what point any given filter will or will not be overcharged in respect of its defecating function by the oxidation or entanglement of dead matter. But the question of the filtration of living germs is altogether more obscure. We know that many of them are caught and effectually intercepted by both surface and underground filtration; but we do not know in what proportion this intercepting takes place, either on the average of all germs or with reference to each kind of germ which may be present—different questions not always sufficiently distinguished. Then we also know that the life of some germs is destroyed if their development be too long retarded. Bateman, Michael Scott, and others afterwards have described the remarkable effect which storing water in dark tanks has in keeping it clear, not only while it remains in darkness, but even under subsequent exposure to light. Now we have at present very little quantitative or well-digested knowledge on these subjects. In fact, little more is known of them than is contained in the crude statement which I have just laid before you. We have no series of experiments to show what or how many germs escape a given process of filtration or storage; and it is not every germ that we need be afraid of: the greater part of them, probably, are quite innocuous. All that the chemists have been able to give us is a dubious estimate of the total quantity of organic matter (whatever that term may mean) which the influent and effluent waters severally contain. They do not and cannot tell us in what form the matter exists, whether dead or alive, animal or fungoid. Now for many purposes the information so given is about as useful as it would be to know that there is animal and vegetable life in a given field, without being told whether it is corn or couch grass, rats or rabbits. On this subject I think both the engineer and the chemist will but grope in the dark until the biologist comes to their aid, working statistically with his microscope as well as observing particular developments. Whether any observers are yet prepared by preliminary knowledge for such investigations I know not, but sure I am that the need of them has come

It may be some consolation to the timid or fastidious among my listeners to be assured, first, that only a few organic germs are capable of hurting us, and, secondly, that an overwhelming proportion of the germs of life perishes without reaching maturity or attaining the power of doing mischief. This destruction goes on to an extent little dreamt of except by those who have minutely examined the question It is not an exaggeration, but in many cases an under-statement, to say that a million germs are produced in most of the lower forms of life for one which ever reaches the reproductive stage in its turn Numerical evidence is easily obtained of this in the case of ferns and lycopodiums and fungi among plants, and of many worms and fishes and other creatures of lower organization among animals This constitutes at the same time our safeguard and our danger a safeguard, by the improbability of our meeting the few survivors of this enormous destruction; a danger, from their rapid increase when they do happen to meet with a resting-place favourable to their development

What is practically becoming most essential to us just now is to be able to pass from vague generalities, such as these, to definite and quantitative statements.

No doubt much may be done, and is daily being done, to come to the assistance of these natural processes of purification by submitting water of doubtful quality to various operations calculated either to remove certain classes of impurity, or to avoid clogging or otherwise overtasking the natural or other filters But at present we are working in the dark, and empirically, in fact, applying quack remedies at random, instead of setting to work systematically and intelligently. Much fuller knowledge must be acquired before we can understand our business

In the meanwhile I think we must view with great and increasing distrust all merely selective sources of water supply, and that, except perhaps in some favoured localities, such as the best of the gathering grounds from which Glasgow is happily supplied, we must not put too implicit confidence in any methods of filtration or boring

Besides, then, the general investigation which I have just spoken of, there remain two alternatives to consider, each of daily increasing importance in certain localities One is the separation of the drinking from the ordinary supply, the other is the distillation of the drinking-water Neither of these are new; and there are many places where they are of obvious necessity, and practised with the greatest care accordingly. I think both require more attention than they have received in this country.

As regards the separation of supply, it surely is not seemly that where there is no scarcity of water, but only a scarcity of wholesome water, the waterclosets and factories and condensers of steam engines should be put in competition with the dry throats of the people for the drinkable supply

The question of distillation also requires further study. There seems to be no doubt that by subjecting water to sufficient heat we can destroy every living germ in it, and that by distillation we may combine this with the removal of almost all inorganic matter. At present the process seems to be rather expensive, and brings it up to a price which is far too high for its general use But I think that when the process comes to be carefully gone into, with a view to working it upon a very large scale, it may not be found impossible to effect a considerable saving upon this cost. In fact, the mere necessity of delivering the distilled water at as low a temperature as possible, without the use of too much cooling material, is a security for the employment of as little coal as possible We should require a settlement with the Excise to prevent the revenue suffering by fraud; but no doubt a compromise could be arrived at if the necessity were felt to be urgent.

The collection and arrangement of my thoughts, with a view to the remarks just addressed to you, has brought before my mind very strongly certain considerations, some of which, being partly of a political character, I shall rather indicate than discuss.

In the first place, there is an evident and urgent necessity for the whole question of the water supply, at any rate of England, being much more thoroughly investigated and taken in hand than it has hitherto been thought necessary.

Secondly, there is need for the concentration of the business of the supply and distribution of water (including frequently the management of the gathering grounds), the roads, the lighting, and the drainage in one board for each town or district, preferably the municipal authority. In London, where there is no such concentration, the waste and inconvenience arising from the independence of the road, gas, and water authorities in the mere matter of breaking up the roads is becoming a very serious consideration.

Thirdly, there is a want of knowledge of natural science in the local governing bodies, which is but ill supplied by their employment of professional officers. Much more of it is wanted in the governing councils themselves before their technical advisers can be either properly appreciated or properly controlled. Whether this is to be got by the direct infusion of a professional element into the council itself, or whether it is best to wait for the general spread of natural knowledge, I scarcely care even to form a judgment.

Fourthly, it is a popular delusion, especially prevalent in this Section, that the invention and provision of a mechanical convenience are necessarily an immediate social benefit. There are many cases in which the direct effect is to facilitate personal indolence or carelessness. It is then a positive evil, until, either by natural selection or by experience, more careful habits have been reverted to. There are other cases in which the indirect consequences are more mischievous than the direct advantages are beneficial. Here, again, there is no benefit until those consequences have been met. There is a disadvantage which only attaches to the immediate effects of some particular inventions. On the whole, of course, invention is not only a good thing, but, together with discovery, a necessity of our nature and of our existence. Meanwhile our immediate national necessity is a wider, deeper, more exact, and more general spread of natural knowledge.

On the Removal of Subaqueous Rocks by the Diamond Rock-borer.
By Major Beaumont, *M.P.*

On the Removal of Sand-bars from Harbour-mouths. *By* M. Bergeron.

Hand-machine for Shaping and Finishing Metal Surfaces. *By* J. B. Beynon.

A Flanging-iron and Steel Plates for Boiler purposes. *By* A. B. Brown.

On an Engine for Starting and Reversing large Marine Engines.
By A. B. Brown.

The principal feature of this engine consisted of a combination of steam and hydraulic cylinders, controlled by an automatic valve-gear, which enables the engineer to reverse the largest engines without assistance in a few seconds. This is accomplished by the lever which opens and closes the steam and hydraulic valves being hung partly on the reversing-lever and at its other extreme on the weigh-shaft lever, so that any motion given to it and the valves by the engineer in one direction is counteracted by the movement of the weigh-shaft lever to which the links of the marine engine are attached. In this way these links follow the motion of the reversing lever, and are locked fast at any degree of expansion in the quadrant

On a Machine for the Liquefaction of Gases by combined Cold and Pressure. *By* J. J. Coleman, *F.C.S.*

This paper describes a powerful machine, erected for dealing with 300,000 feet per day of waste gases at the works of Young's Paraffin Light and Mineral Oil Company

The machine includes—

1st The pumping of the gas by steam-power into a system of tubes externally cooled by water, and from which condensed liquids are withdrawn

2nd Employing the condensed gas, after being deprived of liquids, for working a second engine coupled with and parallel to the first, thus recovering a portion of the force originally employed in compression

3rd Employing the expanded gas, having had its temperature reduced in the act of doing work, as a cooling agent for a portion of the condensers to near zero Fahrenheit

On Drainage Outlets through Slob Lands. *By* A. Crum-Ewing.

The author described the means he had employed to open up a channel [illegible] miles long through slob, in the colony of Demerara, for the purpose of reestablishing natural drainage This slob is a deposit from the great rivers of the northern part of South America, and when it sets in in front of the plantations, completely blocks up their drainage outlets The method employed was to lay a steel rope all the length of the mud-bank, and, by means of Fowler's clip-drum placed in a small steam-vessel, which had strong drag-harrows attached, to run the whole apparatus rapidly from end to end of the rope When the water discharged from two very powerful centrifugal pumps was brought to bear after the dredge, a marked effect was produced, and a channel was being rapidly opened deep enough and wide enough to carry off the heavy rainfalls (sometimes as much as six inches in twenty-four hours) without having recourse to pumping—a matter of great consequence, as the expense and risk of pumping are large.

On recent Attempts at Patent Legislation. *By* St. J. Vin

On the Form of Blocks for Testing Cement. *By* G. F. Deacon.

On the Strength of Concrete as affected by delay between mixing and placing in situ. *By* G. F. Deacon.

Description of Stobcross Docks. *By* J. Deas.

The first portion of ground purchased for the works was in 1845, and consisted of 35 acres At that time a wet dock and tidal basin were proposed, having a total water space of 17 acres and 16 acres of quay space, the length of quayage being 1458 yards. Until within the last few years, however, the Clyde trustees were able to obtain ground on both margins of the river sufficient for the required quay extension, the river itself forming the water space, and requiring little expense to make it available opposite the new quays.

In 1864 the Edinburgh and Glasgow Railway Company (now merged in the North British Railway Company) obtained an act to make a railway from their Helensburgh branch to the authorized docks, with a station immediately on the north side of the docks, but nothing was done till 1870, when the Clyde trustees obtained an act for enlarged docks &c, and the railway company an act for the removal of the site of the station

Under their act the Clyde trustees purchased additional ground to enable them to carry out the works now authorized The large cartoon plan showed the general outline of the docks and the diversion of the Pointhouse Road &c The road is 55 feet wide, and extends from Sandyford Street to Stobcross Street, or a length of 980 yards, it has been formed entirely in cutting, the average depth being 29½ feet, the greatest depth [illegible] feet and the total quantity removed was nearly 300,000 cubic yards, of which about a fourth was boulder clay Only the immense power of dynamite enabled this to be removed The cost of the road, including land, was about £45 000

The docks will be tidal, and when complete will afford 33½ acres of water space 20 feet deep at low water and will comprise three basins The entrance from the river is at the west end of the docks and is 100 feet in width, communicating with an outer basin 695 feet wide at its widest part and two inner basins, 270 feet and 230 feet wide respectively, the pier between being 195 feet wide The total area of quay space will be 27½ acres and the length of quays about 3342 yards

The entrance will be spanned by a swing bridge worked by hydraulic power, and capable of carrying a rolling load of 60 tons There will also be four coaling-cranes, each capable of lifting 20 tons also worked by hydraulic power The bridge, cranes and the necessary hydraulic machinery are being constructed by Sir W G Armstrong & Co The quays will also be provided with sheds grain-stores, &c, and lines of rails

From the borings made on the line of the quay walls, it was ascertained that the strata were of the worst possible kind in which to construct such works, consisting as they do (excepting at the north west corner, where boulder clay was found) of water bearing gravel and sand, interspersed with pockets of mud and that to reach the rock with the foundations, except along a portion of the north quay, would be out of the question A longitudinal and a cross section of the site of the docks, showing the strata as ascertained from the bores, were shown on the cartoons

For the portion of north wall in the boulder clay, and where the rock was within a depth of about 40 feet under cope level, the usual section of wall has been adopted, but for the remainder of the walls and bridge seat, where the stratum is of sand and gravel &c, charged with an enormous quantity of water especially under low-water level, and the rock at a depth of from 50 feet to 100 feet below cope-level, the system of cylinder substructure recommended by Mr Bateman and the author of this paper in 1860 and successfully carried into effect in the construction of Plantation Quay wall and 60-ton crane seat there, in 1870–75, was again fixed upon A small portion of the west wall of the dock is founded on sheet and bearing piles where the boulder-clay suddenly dips, and a timber-wharf outside of the dock-entrance, where the quay may be of a less permanent nature

The cartoons showed the general details of the whole of the sea-walls, as well as of the bridge-seat

The first contract, embracing the entrance and western portion of the docks' walls, was let in August 1872, the amount being fully £160 000

The whole of the cylinders are of concrete, composed of 5 of gravel or broken stones and sharp sand to 1 of Portland cement of the strongest description, mixed together by steam-power with the necessary water The cylinders for the quay-walls are about 27 feet 6 inches in height, made up of rings 2 feet 6 inches deep, the thickness being 1 foot 11 inches These rings are formed within wooden moulds, on a platform, and, to facilitate lifting and break bond when built into the cylinder, they are divided into three pieces and four pieces alternately The dividing of the rings is effected by iron plates placed across the mould in the positions required The corbelling or bevelling of the bottom ring is done by placing contracting pieces in the mould on which to shape the ring The seat for the iron washer on the top of the first, or "corbelled ring," and the holes for the bolts to secure the same to the iron shoe are also formed in the moulding of the rings The concrete, as it is filled into the moulds, is well rammed with rammers weighing

25 lb., so as to secure homogeneity and a smooth surface. Twelve hours after filling the moulds the division-plates are withdrawn, and two days thereafter the moulds are removed from the sides of the rings, and in a period varying from nine days in dry hot weather to three weeks in rainy weather, the rings are ready for removal and building. The content of one ring complete is 10½ cubic yards and the weight 18 tons, the heaviest portion weighs about 6 tons.

The shoes are of cast-iron, 2 feet deep, of the same external shape as the bottom of the cylinder, of 1-inch metal, with a bevelled inner shelf on which the corbelled ring of the cylinder rests, and to which it is secured with a malleable iron ring or washer, 5 inches by ¾ inch thick, held down by 1¼-inch bolts. The shoes of the ordinary triune cylinders weigh about 4¾ tons each, and, for convenience in handling, are made in six parts.

In the construction of the cylinder substructure, a trench is made in the line of the foundation (the bottom being about low-water level), of the necessary width, and slopes of about 1½ horizontal to 1 perpendicular, over which, or alongside, is erected the necessary staging to carry the travelling cranes and digging apparatus. The shoes are placed on the bottom of the trench in proper line and position, the concrete rings are then built up in rings of three and four pieces alternately, pointed in cement, and the digging out of the sand or gravel &c. within the cylinder-wells is commenced. Special diggers or excavators have been designed for this purpose.

A load of from 300 to 400 tons of cast-iron weights is generally required during the sinking of each triune group of cylinders, to assist in sinking it to the proper depth, which is 48 feet 7 inches from the cope-level of the quay to the bottom of the shoe. The average rate of sinking is about 12 inches per hour in good working sand, however, as much as 3 feet per hour has been attained.

When each group of cylinders is sunk to the proper depth, the wells are filled to the top with Portland-cement concrete, lowered to its place carefully.

To effectually close up the apertures formed by the joining of each two groups of cylinders, a timber chock-pile, 25 feet long by 9 inches square, is driven behind, anglewise, so that a sharp corner may bear hard against each of the cylinders.

The foundation for the swing-bridge consists of twelve concrete cylinders, each 9 feet in external diameter, 29 feet in depth by 23 inches thick, formed in rings, and resting on cast-iron shoes, as described for the quay-wall foundations. After the cylinders were sunk, they and the interstices between them were cleaned out and filled to the top with concrete, chock-piles being driven where required. On the cylinder-foundation thus formed, a stepped ashlar pier, 16 feet square at the bottom and 10 feet square at the top, by 7 feet high, is erected, with a block of granite 7 feet square by 3 feet 6 inches deep, on which the centre lifting-press of the bridge rests. This pier is surrounded by concrete rubble, the whole forming a mass of masonry 36 feet 6 inches by 32 feet 6 inches by 10 feet 6 inches high.

The foundations for the hydraulic rams, capstans, and side walls of the bridge-pit are formed on single concrete cylinders placed apart and spanned between by brick arches. The cartoons showed the details of the foundations.

The first of the ground acquired for the docks was bought in 1845, at 6s. 6d. per square yard, and the last in 1872, at 35s.

The total cost of the docks, when fully equipped, will approach £1,500,000.

Improved Safety-Apparatus for Mine-Hoists and Warehouse-Lifts.

By Thomas Dobson.

This apparatus, for checking the downward movement of the cage, or hoist-box, in case of the breaking of the suspending-rope or gear, consists of a mechanical arrangement of levers, which expand through the intervention of a spring acting upon the inner end of such levers through a sliding-sleeve, and so "strutting out," as it were, against the guides, or by gripping the guide-ropes, where ropes are employed instead of upright timbers.

On the Application of Spring Fenders to Pier-heads. By Mortimer Evans.

On a Safety-Lock for Facing-points. By Mortimer Evans.

On the Experiments made at the Camp at Aldershot with a new form of Military Field-Railway, for rapid construction in war time. By J. B. Fell.

Field-railways are now recognized as being amongst the most important appliances in modern warfare; but hitherto it has been found impossible to have them constructed with such rapidity as to be available for the transport-service at the commencement of a war.

The Crimean war was far advanced before the Balaclava railway was finished. The Abyssinian war was over about the same time as the railway from Zoolla to the Koomaylee Pass was completed.

The railway made by the German army in the Franco-German war was not ready for working until within a few days of the fall of Metz, when it became useless.

The railway sent out to the Gold Coast was absolutely useless, and the difficulties and dangers of the expedition were much increased by want of the means of transport which the railway might have afforded for the first 30 miles on the road to Coomassie. Consequently the use of field-railways to a great extent depends upon the rapidity with which they can be constructed.

The cause of the partial failure of the military railways hitherto made is to be found in the impossibility of executing the works of which ordinary railways consist, such as cuttings, embankments, and masonry, with the rapidity necessary for laying down a field-railway at the commencement, or even in the early part of a war.

Our Government have therefore had under consideration the practicability of adopting some other method of construction by which the difficulties hitherto experienced might be overcome. For this object the Royal Engineer Committee at Chatham have had a series of experiments carried out at the camp at Aldershot, of which Captain Luard, R.E., and the writer of this paper had charge. The experimental railway consisted of a succession of timber viaducts, which supplied the place of earthworks, culverts, and bridges, and which, when the materials had been prepared, could be erected with great rapidity. The conditions the Committee desired to have fulfilled in the trials were, that an engine, not exceeding six tons in weight, should take a train of thirty tons up an incline of 1 in 50, and travel at an average speed of 10 miles and maximum of 20 miles an hour. The waggons were required to carry a load of three tons of dead weight each, and from 300 to 500 cubic feet of bulky articles, such as tents, hay, and commissariat stores. A seven-ton siege-gun was to be carried on two waggons; and it was to be shown to be practicable to construct one mile of railway per day over such ground as was selected by the Committee at Aldershot, by the labour of 500 men.

The experimental railway was one mile in length, the gauge 18 inches, steepest gradient 1 in 50, the sharpest curve 3 chains radius, and one of the viaducts was 660 feet in length and 24 feet in height. The structure was of a simple form, and consisted of two beams, which were bolted to a kind of trestle-work supports, which were sunk to a depth of 12 inches and firmly fixed in the ground, the rails being laid on the beams, completed the railway, for the construction of which no other than military labour was required.

The experiments occupied at intervals a period of twelve months, and the Committee came to the conclusion that the result of the trials had proved that the above-named conditions had been in every respect complied with and exceeded.

It had been shown that a single line of field-railway, constructed on the system employed at Aldershot, would be capable of carrying ammunition and commissariat stores sufficient for the supply of an army of 100,000 men; that a double line, and day and night service, would be capable of supplying an army of 300,000 men; that a single line of railway could be made, over ground similar to that at Aldershot, at the rate of 2 miles a day by 500 men; and that, if it should ever be required, it would be possible to construct a field-railway at the speed at which an army of 100,000 men could march.

Besides the Royal Engineer Committee, a considerable number of civil and military engineers, both English and foreign, were present at the experiments.

In the course of the trials and subsequently improvements have been made in the form, materials, and details of the structure, by which the carrying powers and the efficiency of the railway have been considerably increased.

An ordinary transport ship accompanying an expedition would carry the materials and rolling-stock for 12 miles of field-railway, and the 'Great Eastern' steam-ship would carry from 70 to 80 miles.

The cost of the mile of railway at Aldershot, with sidings, stations, and rolling-stock was £3500, and a similar railway of 2 feet 6 inches or 3 feet gauge, to be worked by engines of ten tons weight, and waggons carrying loads of six tons each, could be made for about £5000 per mile, the cost of erecting included.

Although a railway made on the system above described could not be expected to carry the same amount of traffic as one 4 feet 8½ inches gauge, made in the ordinary way, it would be quite capable of performing the whole of the transport service for a large army in the field in a more efficient manner than it could be done by horses, at a much less cost to the country, and, in the opinion of military authorities, the value of such an improved method of transport in war-time could scarcely be overestimated. A difficulty, and perhaps the principal one remaining to be overcome, in practically carrying out this or any similar improved form of field-railway, is the necessity of incurring the expense in peace time of making provision for a future war, and no Administration would willingly assume the responsibility of such increased expenditure unless it were approved and required by the public opinion of the country. It is therefore desirable that publicity should be given to the experiments already carried out by the Government at Aldershot, and that the subject of the best method for the rapid construction of field-railways in war-time should be fully and freely discussed.

Railways on Three-foot Gauge in the United States.

By Capt. Douglas Galton, *C.B., F.R.S.*

In recent years a considerable development of these lines has taken place. The railway in the United States is the pioneer road, it must be made as cheaply as possible at first, and improved as population increases.

There are at present 7073 miles projected and 2700 completed. The Denver and Rio Grande is intended to be 1700 miles long, of which 210 miles are completed. The estimate of cost of a narrow-gauge line in a prairie country is given by the promotors at £1900 per mile for line and £758 per mile for rolling-stock. I ascertained that the cost of the Montrose railway (28 miles long) was £2300 per mile, with two locomotives, two passenger-cars, one baggage-car, and thirteen freight-cars. This is a purely agricultural line, running up into a country up a high elevation, and with small traffic. The Parker and Karns City railway cost £5500 a mile, but it is only 10 miles long at present, and has an equipment of four locomotives, five passenger-cars, forty-six freight-cars, and a viaduct 400 feet long and 74 feet high. This line is for opening out an oil district.

The curves on the lines are in some places 120 feet radius, and some gradients are as much as 1 in 40.

The rolling-stock is as follows:—Engines for passenger traffic have a rigid wheel-base of 6 feet 6 inches, with four driving-wheels (coupled) of from 3 feet to 3 feet 4 inches diameter, the weight on each driving-wheel from 2 tons 4 cwt. to 2 tons 8 cwt.; total weight of engine from 24,000 lb. to 32,500 lb.

Freight-engines have six wheels coupled, and the wheels are from 33 inches diameter in some patterns to 40 inches diameter in others, and the weight on each driving-wheel is from 1¼ to 2 tons; the total weight of these engines is 20,000 lb. to 38,000 lb.

In the cars, the wheels are 24 inches diameter; they weigh from 15,000 lb. to 17,000 lb., and carry thirty-six passengers; they weigh from 410 lb. to 470 lb.

per passenger. The 4 feet 8 inch gauge cars weigh from 28,000 lb. to 33,000 lb., and carry from fifty to seventy passengers, or from 500 lb. to 600 lb. per passenger. The 3-foot gauge cars are 7 feet wide, which allows double seats on one side and single seats on the other, with an aisle down the centre. Recently the cars have been increased to 8 feet in width, which allows of four seats abreast, or a total of forty-seven passengers.

The freight-cars have wheels of 20 inches diameter. The covered freight-car weighs 10,000 lb. as against 17,000 lb. or 18,000 lb. for similar cars on the 4 feet 8 inch gauge, and the narrow-gauge cars carry 8 tons as compared with 10 tons carried on the standard gauge. Thus a train of sixteen cars of the standard gauge would load twenty cars on the narrow gauge, and the total weight of the narrow-gauge train would be 260 tons against 290 tons for the standard gauge, *i. e.* a saving of 30 tons, equivalent to 22 tons of additional freight.

Thus on the narrow gauge the paying load bears a greater proportion to the dead weight than on the standard gauge.

But the heavy weight of cars on the standard gauge has been brought about by necessity of strength to resist shocks received in course of traffic.

The narrow gauge has been hitherto constructed so as to be as light as possible, and the scantlings have been made in proportion to gauge; but evidence is already given of a desire to increase the weight, and the weights carried on the cars show that it is probable increased strength, *i. e.* weight, will have to be resorted to.

The great width which is coming into use for the cars, *e. g.* 8 feet on a base of 3 feet, must be unstable; and I do not think that this mode of increasing the proportion of paying weight can stand. But if cars of 8 feet wide are run but little economy can be claimed for the 3-foot gauge on the ground of diminished width of railway.

The longer tracks of the United-States railways enable all the plant to pass easily round curves and the use of radial axles also contributes to that end; and there was at the Exhibition the Miltimore axle, of which a specimen which had run 12,000 miles was shown, in which the wheels move on the axle independently of the axle, thus materially diminishes friction on curves. A train with these axles has been running on the 3-foot railway in the Centennial grounds. These appliances enable the standard gauge to be constructed with curves practically as sharp as those on the 3-foot gauge.

The weight of rails depends on weight of engine: a standard-gauge engine can be made as light as the 3-foot-gauge engine, but the light engine will not draw heavy weights up the steep inclines necessary for a line which follows the contours of the ground. In the United States the 3-foot gauge has the conveyance of cars which can be more easily moved at stations than the cumbrous cars of the standard gauge.

The break of gauge entails a cost for transhipment of from 10*d.* a ton where the traffic is regular to 1*s.* 6*d.* to 2*s.* a ton where it is intermittent. The line may be useful as a pioneer line; but when the traffic becomes large it will have to be converted to the standard gauge. A standard-gauge line would answer all purposes, if made with a light rolling-stock.

On an Improved Grain-sieve. By J. H. GREENHILL.

On Improvements in Railway Appliances. By R. R. HARPER.

Dock- and Quay-Walls, Foundations, &c. By T. S. HUNTER.

In this paper the author described the construction of dock- and quay-walls, foundations of bridges, subways or tunnels, sewers, and works of a similar nature, and also the means used to facilitate such works.

In carrying on operations where the sinking of foundations has to be effected in situations where water permeates the sand or soil so as to flood the works, a dam may be employed, wholly or partly composed of clay tipped in front of the line of foundations, a space for which has previously been dredged to the required depth when necessary, or, in the event of clay not being within reach, an embankment may be constructed composed of the local soil, faced with clay and coated with stones in order to insure its stability. A water-tight dam is thus formed, and the excavations for the foundations may be further protected by the insertion of piles, either driven or screwed into the inner slope of the dam and also into the opposite side of the cutting. The piles have vertical grooves, into which a timber boarding may be slipped, thus forming a thoroughly dry box-dam in which foundations may be built *in situ*, or if no such box-dam be formed, the foundations may be sunk by means of excavators.

For the construction of bridge piers in open water the site may be dredged to the required depth and clay deposited, so as to form an embankment rising above water-level, down through which an excavation is made and the foundations built, or through which they may be sunk; they may also be floated into position.

To construct subways beneath water the river bed is dredged, and clay mixed with ground chalk and cement deposited so as to form a water-tight roof to the operations and the subway may be formed by tunnelling through the body of the clay, ground chalk, and cement, if deposited in sufficient quantity.

The foundations may be formed of masses of stone masonry, brickwork, or concrete, whose horizontal section consists of two members at right angles to one another, these members being hollow to permit of excavation being carried on in their interior while being sunk. Tongues or grooves of a semicircular or other shape are formed on the ends of one of the members, the other constituting a counterfort.

For the purpose of facilitating the sinking of foundations, the toe or bottom should be surrounded with a shoe or curb.

The author then described at length the drawings which were exhibited.

In conclusion he stated, it is of the utmost importance that every facility should be given to the free action of the ebb and flow of a river, because an obstruction weakens its action, thereby withdrawing a certain amount of force from its power. The advantage of these walls is that they offer comparatively little resistance to the water.

Walls of this description might be faced with hard rubble-stone of from 3, 4, 5, 6, 8, and 10 cwt. each, the remainder of brickwork or concrete. Roman cement or hydraulic lime ground with mine-dust or puzzolano might be used with advantage in the work if of rubble built *in situ*.

When the deposition is of great depth, as in the Clyde, varying from 60 to 90 feet in some places, the breadth of base cannot be overestimated, more particularly where subject to great weights. From this construction a base of 32 feet or more would be obtained, thereby giving great stability, also affording accommodation for water-, gas-, and sewage-pipes.

The alveus or channel of a river is subject to move upwards as well as sidewise, from causes not always in the immediate vicinity but at a distance.

On Reuleaux's Treatment of Mechanisms. By Prof. A. B. W. KENNEDY.

Importance of Hydro-Geological Surveys from a Sanitary point of view.
By BALDWIN LATHAM, C.E.

The author in his paper pointed out that all subterranean stores of water were due to the rainfall percolating into the earth, but that there were matters which affected the quantity of water percolating, such as the nature of the outcrop of the strata receiving the rainfall, the volume of the strata, the lithological character, and the free communication between different parts. The water held in store in the earth did not as a rule, maintain a horizontal level, but the surface possessed a considerable fall in directions corresponding to the points of the discharge of the springs. The inclined surface of the water pointed to its movement in the direction of its outfall or natural vent The water-level, therefore, of subterranean strata meant a line drawn from the highest point at which it accumulated to the lowest point of vent The inclined surface of the water was the measure of the element of friction and molecular attraction which interfered with the free discharge of the water, so that it was retained in subterranean reservoirs and but slowly discharged from them The subterranean currents obeyed the same laws, with reference to their flow, as streams which move on the surface of the earth A number of examples were given as to the rates of fall of subterranean water, and also as to the elevation to which water did rise in particular years in the earth It was shown that the elevation of the subterranean water between the town of Watford and the highest spring which issued from the chalk hills was 300 feet in a distance of fourteen miles, and between the Colne and the River Thames at London Bridge, a distance of fourteen miles, the water fell at the rate of 13 feet per mile Near the Middle Chalk the rate of fall varied from 13 feet 6 inches to 19 feet 0 inches per mile, and in the Tertiary beds at Garrett the fall was 5 feet per mile, and in the same formation at Waltham Abbey 4 feet per mile The well of Gromille, in the Lower Greensand, indicated a fall of 2 feet per mile A table was given showing the rate of fall of subterranean water in the neighbourhood of Croydon, which was shown to vary from 8 feet per mile to 94 feet per mile, and the subterranean water, as ascertained by wells sunk in the boulder-clay at East Dereham, Norfolk, showed that the water level varied from 2 feet in a mile in the flat tableland to 100 feet in a mile in the valleys The author pointed out the importance of pure water with regard to health, and gave several examples showing the deleterious effects of the drainage from cesspools and cemeteries upon water-supply and the health of the persons using it he also pointed out the importance of ascertaining [illegible], in reference to the construction of wells and cesspools, and that a small amount of consideration with regard to the relative positions of the well and cesspool in a country-house may make all the difference between rendering it healthy or unhealthy With regard to epidemics of enteric fever, whether directly ascribed to water or milk, the author observed that in every case recorded the water had invariably been procured from wells, and while it was singular that so much attention was paid to the pollution of rivers flowing over the surface of the ground, which had never been traced to be the cause of disease, no one had thought of the great evils which had resulted, and would result, from the pollution of underground sources of water-supply The object of the author was to direct attention to this important subject, and to point out that where the use of cesspools was unavoidable, there were ways in which they might be introduced without the possibility of polluting the water-supply when it can only be procured from a local well

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On the Direct Motion of Steam-Vessels By R MANSEL

On the Strength and Fracture of Cast Iron By W J MILLAR.

The object of the present communication is to describe certain phenomena observed by the writer when engaged in testing cast-iron bars

The bars were about 40 inches long, 2 inches deep, and 1 inch broad The distance between supports (or span) when placed in testing-machine was 36 inches. The load was applied gradually and at centre of span

In general the bars broke with straight fractures, the direction of fracture being in line of application of load In some cases, however, curved forms of fracture were observed

During the course of testing it was observed that the curved fractures divided the span more or less unequally, whilst the straight fractures, with few exceptions, divided the span into equal portions

After a carefully conducted series of experiments, the writer finds that the *form* of fracture conclusively points out the *position* of fracture, viz that bars showing straight fractures have broken at or close to centre of span, whilst bars showing curved fractures have broken at points more or less removed from centre of span, and that in general the curve of fracture *increases* with distance of fracture from centre.

In all cases the fractured parts were found to fit exactly together, no piece of the metal being thrown out on fracture taking place, and where the fractures were curved the line of fracture pointed towards point of application of load, the results of several experiments showing that fracture commences at the convex side of the bar and passes upwards, gradually curving towards centre of span

The curved fractures occur also in bars of 1 square inch section, their forms not being, however, so well marked as in the bars already referred to

With a view to obtain the relative strength of bars showing straight and curved fractures, a note was kept of the breaking loads, deflection, forms, and positions of fracture, the result of which is given in Table I

(The results given in the following Tables are all from bars of 2 inches deep, 1 inch broad, and 30 inches span)

TABLE I.

Position of Fracture.	Number of Bars	Average Breaking Load	Average ultimate Deflection.
		lb	inch
At centre of span, *straight fractures*	20	3584	·393
At points from ⅝ inch to 3½ inches removed from centre of span, *curved fractures*	25	3551	380

The above results show a slight excess of strength in bars breaking at centre of pan and with straight fractures

In general the deflections were found to increase with increase of load, but in ome cases, the bars being exceptionally strong and remaining unbroken, a decrease f deflection accompanied an increase of load

The results obtained from 14 such bars are shown in Table II.

TABLE II.

Average results obtained from 14 unbroken bars with increasing Loads.

Loads to which bar was subjected	3360 lb	3930 lb.	4480 lb.
Average deflections at these loads	327 in.	·317 in	313 in.

Table III. contains the results of some experiments made to determine the amount of "set" which took place in bars when subjected to several applications of the same load.

TABLE III

Load applied 2800 lb.

	Bar No 1		Bar No. 2.		Bar No 3.		Bar No 4.	
	Def. inch	Set inch	Def. inch.	Set. inch.	Def. inch.	Set. inch.	Def. inch.	Set. inch.
1st application of load	302	021	330	·020	·290	012	298	015
2nd " "	282	·003	317	·005	290	005	·296	·002
3rd " "	270	001	310	·001	280	003	285	·002
4th " "	278	·000	·312	·000	282	·000	·281	·000
5th " "	·270	·002	·313	·000	—	—	—	—
6th " "	273	·001	·315	·000	—	—	—	—
	Finally broke about 3500 lb. Def. ·403		Finally broke at 4270 lb Def. 518		Finally broke at 4330 lb Def. ·455		Finally broke at 3760 lb. Def. ·395	

From these experiments it appears that the "set" *decreases* with successive applications of the *same* load.

This decrease of set also appears to obtain even when the load applied is an increasing one.

The results obtained from 10 bars are given in Table IV

TABLE IV

Average results obtained from 10 unbroken bars with increasing loads

Loads ..	3360 lb	3920 lb	4480 lb
Average deflection	·341 in	·367 in	·388 in
Average set	·026 in	·014 in	·008 in

On a Spherical Pendulous Safety-Valve By JAMES NASMYTH, *F R S*

On the Investigation of the Steering Qualities of Ships By Prof OSBORNE REYNOLDS

[Printed *in extenso* among the Reports, p 70]

On a New Form of Lamp By R LAVENDER.

The construction of the lamp is a glass lantern 18 inches square, with a funnel or chimney 24 inches high, into which is introduced a jet of steam about $\frac{1}{16}$ inch across when the pressure of steam is about 20 lb to 30 lb per square inch, if the pressure is less the jet must be larger, if higher smaller, the object of the jet being to create a partial vacuum in the lantern—the consequence being that the surrounding air is forced through the burner of the lamp and causes a very complete combustion of the oil

A very brilliant light is produced, which is increased partly owing to the products of combustion being continuously removed and a volume of fresh air being introduced

The lamp or burner is constructed for a circular wick, and upon the principle of admitting the air to play upon the outside of the wick, and also by a disk another column is thrown upon the inside of the wick, another current of air is also carried through the centre of the flame The metal cap is constructed so as to bring the flame into a centre, through the orifice of which it is drawn by the jet of steam in the chimney The oil supply is contained in a shallow vessel, which is heated by a jet of steam before being burned, as many of the oils that may be used would become thick in cold weather

The results obtained from a 4-inch wick have been equal to a light of upwards of six hundred sperm candles, the cost of which, with oil at 9*d* per gallon, is under 1¼*d.* per hour. The oil was supplied by Messrs Young's Paraffin Light Company, and is a product from shale and is a part of the oil that hitherto has been of little use.

The cost of burning an open fire, such as is used at many pit heads, is from ten to twelve hundredweight of coal per night, it is a most uncertain and dangerous light

Whilst the author's lamp was designed for collieries, loading-banks, sheds, sidings, ships, &c., he thinks that it will be of great service to the public.

On Boiler Incrustation and Corrosion. By F. J. ROWAN.

The importance of the subject is alluded to, especially to marine engineers, who have most keenly felt its difficulties, while the range of interests involved by it is as wide as the use of steam

The present state of general information about it being unsatisfactory, we have to seek in a combination of chemistry and mechanical science for the needed elucidation of its problems.

The course of investigation has been marked by the suggestion of various empirical remedies, which are pointed out, but which have failed to reach any good result, the actions to be counteracted not being understood.

Incrustation and corrosion are not one action, but dissimilar ones, although they are often found united in boilers, and therefore both must be noticed.

Incrustation is first considered, Dr. J. G. Rogers, of Madison, U. S., being quoted (from 'Chem. News,' vol. xxvi.) for the non-conductibility of crusts and the proportionate increase of temperature which their presence in boilers renders necessary.

Boilers subject to incrustation are divided into two classes:—

1. Land boilers using natural fresh waters; and
2. Marine boilers using sea-water.

1. The average quality of natural fresh waters is illustrated by analysis of River-Clyde water, as formerly supplied to Glasgow, and an analysis also by Dr. Wallace of crust deposited from that water is given. The case is then quoted of the boilers at a mill in Barrowfield still using that water, but in which the formation of crust is prevented by the use of a quantity of soda-ash.

The action of soda-ash under these circumstances is described; it causes the decomposition of the sulphate of lime and rapid deposition of the neutral carbonate as powder. Where bicarbonate of lime is present, it is also precipitated as neutral carbonate in a powdery form, one equivalent of carbonic acid being liberated. Neutral carbonate being thus formed rapidly, has not power to adhere to boiler surfaces, while, if deposited slowly by heat from the bicarbonate, it is crystalline and does adhere.

M. Bidard of Rouen, author of papers on this subject in 'Annales Industrielles,' has made numerous examinations of boiler-crusts, which show, according to him, that organic matter has power to agglomerate carbonate of lime and form crust by a process of "baking." His opinion is quoted from one of his letters to the author.

Fresenius, quoted in a paper by Dr. Wallace in 'Proc. of the Phil. Soc. of Glasgow,' vol. iv., ascribes this agglomerating power to sulphate of lime. Bidard's explanation applies where carbonate and not sulphate of lime predominates, because sulphate is able to form crusts where no organic matter is present, as in some crusts from marine boilers. The use of too much soda-ash is injurious, and precautions are given, with a little further illustration of its action in boilers.

It is proposed to apply it in the feed-tanks or cisterns generally attached to boilers, allowing the lime to be deposited there to save constant blowing off.

Various other preventives of incrustation are noticed, including De Haen's method of using barium chloride and milk of lime, founded upon the investigations of J. Y. Buchanan (Roy. Soc. Proc. vol. xxii.), and some details of comparative cost in working with this process are given from Dingler's Polyt. J. ccxvii.

As the most complete preventive of incrustation, which is otherwise scientifically desirable, the author advocates the use of surface condensers in connexion with land boilers.

2. Although modern systems of marine engine practice have removed incrustations from marine boilers by the introduction of surface condensation, there is still some necessity to consider incrustation as applying to them, because of a tendency to return to the ancient régime in consequence of difficulties with corrosion. The evil effects of incrustation are felt more heavily in marine practice from its conditions of using sea-water, which contains a large amount of solids, and of limited space for carrying fuel and chemical reagents and for repair of boilers.

The inapplicability of the chemical method is pointed out, reference being made to experiments of Mr. Jas. R. Napier, F.R.S., published in Proc. Phil. Soc. Glasg. vol. iv.

Working with fresh water is the only sensible and efficacious method; but when this has been used it has brought with it the evils of corrosion.

Analyses of sea-water from the Black Sea, and of six samples of marine-boiler crusts found at various pressures, are added, with remarks on some of these by Dr. Wallace (from Proc. Phil. Soc. Glasg.), and extracts from a paper in Dingler's

Polyt. J. ccxii., by Dr. Ferd. Fischer, confirmatory of these remarks, and showing the influence of elevated temperature and pressure on the decomposition of various salts in water.

Corrosion.—Causes of corrosion of exterior of boilers are briefly glanced at, including damp settling, accumulation of damp ashes and of soot, accompanied by careless firing, which causes sulphur, acids, and other corrosives to combine with the soot.

With regard to corrosion of the interior of boilers, investigations on various corroding forces are first quoted. Prof. Crace Calvert's experiments on the action of sea-water and of various gases on metals are alluded to to prove that sea-water exerts such an action upon steel and iron, that carbonic acid in presence of water, acts energetically, and that distilled water, free from gases has no action.

The application of these researches by W. Kent (of the Stevens U.S. Institute of Technology) to the examination of the corrosion of iron railway-bridges in the United States is then referred to, and the investigations of A. Wagner (from Dingl. Polyt. J. ccxviii.), on the influence of various solutions on the rusting of iron, are quoted. This author corroborates Calvert's report of the action of carbonic dioxide, and notes the fact that the presence of chlorides of magnesium ammonium, sodium, potassium, barium and calcium in water largely increases the production of rust, the action of chloride of magnesium alone being increased by heat.

These facts correspond with that observed by J. Gamgee, that lime solutions used as media of congelation in ice making corrode the pipes or channels which convey them.

Stingl's valuable contribution to this subject, viz., his paper on the effects of condensed water containing grease on boilers fed with it (Dingler, Polyt. J. ccxv.), is quoted at some length.

This author proves that grease, with a small quantity of salts of lime and magnesia, at a temperature not exceeding 60° to 70° Cent., forms lime-soap, which, under the influence of a higher temperature, partially decomposes into free fat acid and a basic lime soap which adheres to the boiler-surfaces, the free acid, which is usually oxalic acid, attacking and dissolving the iron. In the crust the fat is recognized by the addition of hydrochloric acid, the separated organic mass being afterwards shaken with ether.

Even with lime and magnesia salts present in very insignificant proportion, the presence of grease is injurious, as, with saponification, under considerable pressure, a small quantity of lime suffices to occasion the splitting up of a neutral fat into free fat acid and glycerine. With low pressure the same action proceeds more gradually.

Various cases of corrosion from greasy water are noticed by this author, and in particular that of a steam-boiler of Cornish design into which the condensed steam from two engines (of 300 and 100 horse-power) was fed. This boiler was constructed of steel, and after only three weeks firing was leaking in the fire-tubes. A deposit was found adhering to the upper part of the tubes, of which the analysis is given. The water in the boiler had a milky appearance which was at once removed by ether. Ether is recommended as a good qualitative test for the presence of grease in water.

The analysis of the condensed feed-water is given, and the various operations in testing the deposit from it also recorded.

Means were adopted to purify this water by precipitation of the calcium carbonate and part of the magnesium carbonate along with the grease which was carried down with the precipitate, and by subsequent filtering, and the analysis of the purified water is given. The boiler afterwards worked for three months with this water without any bad results, a pure deposit, consisting principally of magnesium hydrate and calcium carbonate and sulphate, being found to a small extent on the surfaces of the boiler.

Finally a letter addressed by the author to 'Engineering' (Oct. 1874) is referred to, in order to call attention to the difference between pure natural waters and genuine distilled water, i.e. distilled water free from air. The difference consists in the presence of gases in all natural waters. The distilled water from surface condensers of steamers necessarily contains some air, and it is therefore not "genuine distilled water."

Examples of boilers subject to corrosion are classed under the heads:—

1. Land boilers using natural fresh water, and
2. Marine boilers.

1. Loch-Katrine water, from its great purity, affords the best opportunity of studying the effect of pure natural water on boilers. The former water-supply of Glasgow having been calcareous, the boilers using it became coated with lime, and did not suffer in consequence when afterwards supplied from Loch Katrine. In cases where the lime coating was removed corrosion quickly set in, and new boilers working with Loch-Katrine water from the first were rapidly destroyed. Several examples illustrating these points are quoted, and the remedy adopted is described. This was the formation of an artificial coating of lime by feeding a whitewash for some time into the boilers.

Analysis (by Dr. Mills) of Loch-Katrine water is given, and by reference to the investigations of Calvert and Wagner its action on iron is explained.

2. *Marine Boilers.* Those using exclusively fresh water are cited, viz. Rowan and Horton's and Perkins's, to illustrate the kind of corrosive action known under these circumstances. The author's letter to 'Engineering' gives the remedies used in the case of Rowan and Horton's boilers.

Another instance of a coasting steamer using nearly all fresh water in her boilers, which, however, were destroyed by corrosion, is quoted. This instance was communicated to the Graduate section of the Institute of Engineers in Scotland by Mr. Jas. Gilchrist. It was found by two chemists that the decomposition of iron in her boilers was caused by the use of tallow. The author points out that the chemists did not make allowance for the presence of a small quantity of sea-water in the boilers, and its decomposition setting free hydrochloric acid.

The description of corrosion given by Mr. Miller in his paper communicated to the Cleveland Iron-Trade Foremen's Association is quoted, as this author enters fully into the matter, and describes two examples which well illustrate the general practice of the day in marine engineering. His deductions from the circumstances of these two examples are combated; and the author proceeds to show that corrosion in marine boilers, where a proportion of sea-water is used, is due to decomposition of the magnesium chloride of the sea-water, and to the liberation of the carbonic acid held in solution by repeated boiling.

The popular error that corrosion is due to some change produced in the constitution of water by redistillation is pointed out, as is the fact that in no case of marine practice has distilled water, pure and simple, ever been present so that its effects might be examined.

The author proposes as a remedy the coating of all new boilers with calcium sulphate and magnesium hydrate artificially, and thereafter the exclusive use of fresh water, which does not dissolve such a coating.

On an Apparatus for cleaning Filtering-Sand.

By John Lang, *C.E., Kirkcaldy.*

The sand is tipped from wheelbarrows into a box, in the under part of which there is a diaphragm pierced with many small holes, through which a supply of water under pressure is introduced. The sand is agitated by the current, and the mud and water flow over the top of the box. When the water flows over clear, a door in the side is opened, the clean water is discharged into wheelbarrows below and is conveyed to the filter. The size of the apparatus depends altogether on the magnitude of the supply of water, and its success depends on the size being adapted to the supply. From very many experiments with various sands, the best conditions were found to be that the water should pass through the box with a velocity of from 3 feet 9 inches to 4 feet per minute, and that the box should be 27 inches in height. This apparatus, as used in the Kirkcaldy and Dysart Waterworks, had been found, in respect to thoroughness and in economy, to be very greatly superior to the former machines. It is able speedily to wash fresh pit-sand, or to rewash the sand forming the body of the filter, but it was explained that it was unable to wash the impurities from the filter-scrapings. Neither the old machines nor any mechanical means even in the laboratory are able to do this. By careful experiments, samples of the mud on the surface of the Kirkcaldy filters were obtained separate from the underlying sand, and it was found that 100 parts of the mud consisted of about 95 parts of diatoms, 4 parts of animalcules, and 1 part of inorganic matter, beside the sarcoid matter of the diatoms from which the offensive smell of the mud is derived. The only way to recover the sand from these scrapings is to allow them to be exposed to the air for some years, until the sarcoid matter is decomposed. The flinty valves of the diatoms may then be removed by washing. A portion of the mud passes below the surface into the body of the filtering-sand, and in course of years is spread through its interstices and reaches even to the bottom. This mud consists almost wholly of the frustules of two minute kinds of diatoms, *Orthosira* and *Cymbella*, and by means of the microscope, used sand may be at once distinguished from fresh sand by the presence of these. They are easily removed by washing.

On a Pneumatic Tramway Car. *By* W. D. SCOTT-MONCREIFF.

On an Elevating Steam Ferry. *By* WM. SIMONS.

The object of this vessel is to supersede the present inclined approaches or slips to ferry stations, and therefore lessen the wear and tear in horses and haulage, to enable a greater traffic to be conducted with greater dispatch and economy and on the same level as the adjoining quays. The valuable ground required for slips is unnecessary, and the ferry-steamer is not confined to a special berth or locality.

To effect the above objects, it is proposed to construct a steamer with a centre platform of sufficient capacity for the traffic, and capable of being elevated and lowered to suit the rise and fall of the tide, and thus enable the vessel to receive (*level with the adjoining quays*) waggons, goods, horses, carriages, and passengers.

On the Brake Problem. *By* JAMES STEEL.

On Communications between Passengers and Guards in Railway Trains. *By* W. STROUDLEY.

On Naval Signalling. *By* Sir W. THOMSON, *F.R.S.*

On Steam-Ship Resistance. *By* J. EVELYN WILLIAMS.

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CONTENTS —Rev B Powell Report on the Present State of our Knowledge of Refractive Indices, for the Standard Rays of the Solar Spectrum in different media,—Report on the Application of the Sum assigned for Tide Calculations to Rev W Whewell, in a Letter from T G. Bunt, Esq —H L Pattinson, on some Galvanic Experiments to determine the Existence or Non Existence of Electrical Currents among Stratified Rocks particularly those of the Mountain Limestone formation, constituting the Lead Measures of Alton Moor,—Sir D Brewster, Reports respecting the two series of Hourly Meteorological Observations kept in Scotland,—Report on the subject of a series of Resolutions adopted by the British Association at their Meeting in August 1838 at Newcastle —R Owen Report on British Fossil Reptiles,—E. Forbes, Report on the Distribution of Pulmoniferous Mollusca in the British Isles —W. S Harris, Third Report on the Progress of the Hourly Meteorological Register at Plymouth Dockyard

Together with the Transactions of the Sections, Rev W Vernon Harcourt's Address, and Recommendations of the Association and its Committees

PROCEEDINGS OF THE TENTH MEETING, at Glasgow, 1840, *Published at* 15s. (Out of Print)

CONTENTS —Rev B Powell, Report on the recent Progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science,—J D Forbes Supplementary Report on Meteorology,—W S Harris, Report on Prof Whewell's Anemometer, now in operation at Plymouth —Report on "The Motion and Sounds of the Heart," by the London Committee of the British Association, for 1839-40,—Prof Schonbein, an Account of Researches in Electro Chemistry,—R Mallet, Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron and Steel,—R W Fox, Report on some Observations on Subterranean Temperature —A F Osler Report on the Observations recorded during the years 1837, 1838, 1839, and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham,—Sir D Brewster, Report respecting the two Series of Hourly Meteorological Observations kept at Inverness and Kingussie from Nov 1st, 1838 to Nov 1st 1839 —W. Thompson, Report on the Fauna of Ireland Div *Vertebrata* —C J B Williams, M D., Report of Experiments on the Physiology of the Lungs and Air-Tubes —Rev J S Henslow, Report of the Committee on the Preservation of Animal and Vegetable Substances

Together with the Transactions of the Sections, Mr Murchison and Major E. Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE ELEVENTH MEETING, at Plymouth, 1841, *Published at* 13s. 6*d.*

CONTENTS —Rev P. Kelland, on the Present state of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat;—G L Roupell, M D, Report on Poisons;—T. G. Bunt, Report on Discussions of Bristol Tides, under the direction of the Rev. W. Whewell;—D. Ross, Report on the Discussions of Leith Tide Observations, under the direction of the Rev. W. Whewell;—W. S. Harris, upon the working of Whewell's Anemometer at Plymouth during the past year,—Report of a Committee appointed for the purpose of superintending the scientific cooperation of the British Association in the System of Simultaneous Observations in Terrestrial Magnetism and Meteorology,—Reports of Committees appointed to provide Meteorological Instruments for the use of M. Agassiz and Mr. M'Cord;—Report of a Com-

mittee to superintend the reduction of Meteorological Observations;—Report of a Committee for revising the Nomenclature of the Stars;—Report of a Committee for obtaining Instruments and Registers to record Shocks and Earthquakes in Scotland and Ireland;—Report of a Committee on the Preservation of Vegetative Powers in Seeds;—Dr Hodgkin, on Inquiries into the Races of Man;—Report of the Committee appointed to report how far the Desiderata in our knowledge of the Condition of the Upper Strata of the Atmosphere may be supplied by means of Ascents in Balloons or otherwise, to ascertain the probable expense of such Experiments, and to draw up Directions for Observers in such circumstances,—R. Owen, Report on British Fossil Reptiles,—Reports on the Determination of the Mean Value of Railway *Constants;*—D. Lardner, LL D, *Second and concluding Report on the Determination of the* Mean Value of Railway Constants,—E Woods, Report on Railway Constants,—Report of a Committee on the Construction of a Constant Indicator for Steam-Engines

Together with the Transactions of the Sections, Prof Whewell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWELFTH MEETING, at Manchester, 1842, *Published at* 10*s*. 6*d*.

CONTENTS —Report of the Committee appointed to conduct the cooperation of the British *Association in the System of Simultaneous* Magnetical and Meteorological Observations;—J Richardson, M.D., Report on the present State of the Ichthyology of New Zealand;—W. S Harris, Report on the Progress of Meteorological *Observations at Plymouth;*—Second Report of a Committee appointed to make Experiments on the Growth and Vitality of Seeds;—C. Vignoles, Report of the Committee on Railway Sections,—Report of the Committee for the Preservation of Animal and Vegetable Substances,—Lyon Playfair, M D., Abstract of Prof Liebig's Report on Organic Chemistry applied to Physiology and Pathology;—R. Owen, Report on the British Fossil Mammalia, Part I.,—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants,—L. Agassiz, Report on the Fossil Fishes of the Devonian System or Old Red Sandstone;—W. Fairbairn, Appendix to a Report on the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast;—D Milne, *Report of the Committee for Registering Shocks of Earthquakes* in Great Britain;—Report of a Committee on the construction of a Constant Indicator for Steam-Engines, and for the determination of the Velocity of the Piston of the Self-acting Engine at different periods of the Stroke;—J S. Russell, Report of a Committee on the Form of Ships;—Report of a Committee appointed "to consider of the Rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis;"—Report of a Committee on the Vital Statistics of large Towns in Scotland,—Provisional Reports, and Notices of Progress in special Researches entrusted to Committees and Individuals

Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s*.

CONTENTS:—Robert Mallet, Third Report upon the *Action of Air and Water, whether* fresh or salt, clear or foul, and at Various Temperatures, upon Cast Iron, Wrought Iron, and Steel;—Report of the Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations,—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations;—Report of the Committee appointed for Experiments on Steam-Engines;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland;—J. S. Russell, Notice of a Report of the Committee *on the Form of Ships;*—*J. Blake, Report on the Physiological Action of Medicines*,—Report of the Committee on Zoological Nomenclature,—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable;—Report of the Committee for conducting Experiments with Captive Balloons;—Prof. Wheatstone, Appendix to the Report;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs;—C. W. Peach, on the Habits of the Marine Testacea;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations;—R. Owen, Report on the British Fossil Mammalia, Part II.;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst;—W.

Thompson, Report on the Fauna of Ireland: Div. *Invertebrata*;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at* £1.

Contents.—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Economy of the *Araneidea* made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes;—Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines;—Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves;—L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12*s.*

Contents:—Seventh Report of a Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lt.-Col. Sabine, on some points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-Registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15*s.*

Contents:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck, on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical

Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829,—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain,—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton,—J. Phillips, on Anemometry,—J. Percy, M.D., Report on the Crystalline Flags,—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s*.

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants,—R. Mallet, on the Facts of Earthquake Phenomena,—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes,—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells,—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our knowledge of the Tides;—Dr. Schunck, on Colouring Matters,—Seventh Report of the Committee on the Vitality of Seeds,—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany,—Dr. R. G. Latham, on the present state and recent progress of Ethnographical Philology,—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge,—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant,—Dr. Max Muller, on the Relation of the Bengali to the Arian and Aboriginal Languages of India,—W. R. Birt, Fourth Report on Atmospheric Waves,—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine,—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at* 9*s*.

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn on Water pressure Engines;—R. A. Smith, on the Air and Water of Towns,—Eighth Report of Committee on the Growth and Vitality of Seeds,—W. R. Birt, Fifth Report on Atmospheric Waves,—E. Schunck, on Colouring Matters,—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations,—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847,—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an Introductory Notice by Lt.-Col. E. Sabine,—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10*s*.

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and

Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug 9, 1848 to Sept. 12, 1849,—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion,—W. R Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev T. R Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at 15s.* (Out of Print.)

CONTENTS —R Mallet, First Report on the Facts of Earthquake Phenomena;—Rev Prof. Powell, on Observations of Luminous Meteors,—Dr. T. Williams, on the Structure and History of the British Annelida,—T. C. Hunt, Results of Meteorological Observations taken at St Michael's from the 1st of January, 1840 to the 31st of December, 1849;—R Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds,—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F Ronalds, Report concerning the Observatory of the British Association at Kew;—E Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge,—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849,—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at 16s. 6d.*

CONTENTS:—Rev Prof Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr J Drew, on the Climate of Southampton;—Dr. R. A Smith, on the Air and Water of Towns: Action of Porous Strata, Water and Organic Matter,—Report of the Committee appointed to consider the probable Effects in an Economical and Physical Point of View of the Destruction of Tropical Forests;—A Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr Daubeny, on the Nomenclature of Organic Compounds,—Rev Dr Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida,—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col Sabine, on the System of Meteorological Observations proposed to be established in the United States,—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory,—F Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850 to July 31, 1851;—Ordnance Survey of Scotland

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at 15s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Economy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s.* 6*d.*

Contents:—Rev. Prof Powell, Report on Observations of Luminous Meteors, 1852–53;—James Oldham, on the Physical Features of the Humber,—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull,—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion,—J. J Sylvester, Provisional Report on the Theory of Determinants,—Professor Hodges, M.D, Report on the Gases evolved in Steeping Flax, and on the Composition and Economy of the Flax Plant,—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds,—Robert Hunt, on the Chemical Action of the Solar Radiations;—John P Bell, M D., Observations on the Character and Measurements of Degradation of the Yorkshire Coast, First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth,—R Mallet, Provisional Report on Earthquake Wave-Transits, and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration,—Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued)

Together with the Transactions of the Sections, Mr Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s.*

Contents —R Mallet, Third Report on the Facts of Earthquake Phenomena (continued);—Major-General Chesney, on the Construction and General Use of Efficient Life-Boats,—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat,—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories,—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers,—Dr Gladstone, on the influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof Powell, Report on Observations of Luminous Meteors, 1853–54;—Second Report of the Committee on the Physical Character of the Moon's Surface;—W G. Armstrong, on the Application of Water Pressure Machinery,—J B Lawes and Dr Gilbert, on the Equivalency of Starch and Sugar in Food —Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships,—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s.*

Contents —T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms,—Dr Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3,—C. Spence Bate, on the British Edriophthalma;—J F. Bateman, on the present state of our knowledge on the Supply of Water to Towns,—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds,—Rev Prof. Powell, Report on Observations of Luminous Meteors, 1854–55;—Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery,—Rev Prof Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self Registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s.*

Contents:—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856:—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and Neighbouring Seas, and the physical conditions affecting their development,—P. P Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America,—T. C Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof Phillips, Report on Cleavage and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena Part I.,—Dr T Wright on the Stratigraphical Distribution of the Oolitic Echinodermata,—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C Atherton, on Mercantile Steam Transport Economy,—J S Bowerbank, on the Vital Powers of the Spongiadæ,—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon,—Provisional Report on the Measurement of Ships for Tonnage,—On Typical Forms of Minerals, Plants and Animals for Museums,—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R Mallet, on Observations with the Seismometer,—A. Cayley, on the Progress of Theoretical Dynamics,—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at 15s.*

CONTENTS —A Cayley, Report on the Recent Progress of Theoretical Dynamics;—Sixteenth and final Report of Committee on Experiments on the Growth and Vitality of Seeds;—James Oldham, C E, continuation of Report on Steam Navigation at Hull,—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-Power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall;—Dr. G. Plarr, De quelques Transformations de la Somme $\Sigma_{0}^{t\;-\alpha}\frac{\alpha^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, α étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $a^{t|+1}$ désignant le produit des t facteurs $a\,(a+1)\,(a+2)$ &c . $(a+t-1)$,—G Dickie, M D, Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel,—Charles Atherton, Suggestions for Statistical Inquiry into the extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth,—J S Bowerbank, Further Report on the Vitality of the Spongiadæ;—John P. Hodges, M.D., on Flax;—Major General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, C E., on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Professor W. A Miller, M.D., on Electro-Chemistry;—John Simpson, R.N, Results of Thermometrical Observations made at the 'Plover's' Wintering-place, Point Barrow, latitude 71° 21′ N, long 156° 17′ W, in 1852–54;—Charles James Hargreave, LL D., on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions,—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings,—Professor James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester,—William Fairbairn, on the Resistance of Tubes to Collapse;—George C Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J Park Harrison, M A, Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at 20s.*

CONTENTS:—R Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–58;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the

Collapse of Glass Globes and Cylinders;—Dr E Perceval Wright and Prof. J Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland,—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards,—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain,—Michael Connal and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857,—Report of the Committee on Shipping Statistics,—Rev H Lloyd, D D, Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results,—Prof J R Kinahan, Report of Dublin Dredging Committee, appointed 1857-58,—Prof J R Kinahan, Report on Crustacea of Dublin District,—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India,—George C Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr Vignoles's paper "On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains,"—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories,—R Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof Owen's Address, and Recommendations of the Association and its Committees

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at* 15s.

CONTENTS:—George C Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester,—Dr A Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops,—A. Thomson, Esq, of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahago, Lanarkshire,—Alphonse Gages, Report on the Results obtained by the Mechanico Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self acting Breaks for Railway Trains,—Professor J. R Kinahan, Report of Dublin Bay Dredging Committee for 1858-59,—Rev Baden Powell, Report on Observations of Luminous Meteors for 1858-59;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H Hodgson, Esq, late Resident in Nepal, &c. &c;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—G C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull,—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren de la Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq, F R.S.;—W Fairbairn, The Patent Laws: Report of Committee on the Patent Laws,—J Park Harrison, Lunar Influence on the Temperature of the Air,—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Prof. H. J Stephen Smith, Report on the Theory of Numbers, Part I.;—Report of the Committee on Steamship performance;—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds,—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at* 15s.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1859-60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee,—Rev J Anderson, Report on the Excavations in Dura Den;—Professor Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of the Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to prepare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of

Vibratory Action and long continued Changes of Load upon Wrought-Iron Girders;—R P. Greg, Catalogue of Meteorites and Fireballs from A D 2 to A D 1860,—Prof H J S Smith, Report on the Theory of Numbers, Part II —Vice Admiral Moorsom, on the Performance of Steam vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel,—Rev W V Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena,—Second Report of the Committee on Steamship Performance —Interim Report on the Gauging of Water by Triangular Notches,—List of the British Marine Invertebrate Fauna

Together with the Transactions of the Sections, Lord Wrottesley's Address, and Recommendations of the Association and its Committees

PROCEEDINGS of the THIRTY-FIRST MEETING, at Manchester, September 1861, *Published at* £1.

Contents —James Glaisher Report on Observations of Luminous Meteors,—Dr E. Smith, Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners Part I —Charles Atherton, on Freight as affected by Differences in the Dynamic Properties of Steamships,—Warren De la Rue Report on the Progress of Celestial Photography since the Aberdeen Meeting —B Stewart on the Theory of Exchanges, and its recent extension —Drs E Schunck R Angus Smith and H E Roscoe on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District,—Dr J Hunt on Ethno Climatology or the Acclimatization of Man —Prof J Thomson, on Experiments on the Gauging of Water by Triangular Notches —Dr A Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops —Prof H Hennessy Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound signals during Fogs at Sea —Dr P L Sclater and F von Hochstetter Report on the Present State of our Knowledge of the Birds of the Genus *Apteryx* living in New Zealand —J G Jeffreys, Report of the Results of Deep sea Dredging in Zetland with a Notice of several Species of Mollusca new to Science or to the British Isles,—Prof J Phillips, Contributions to a Report on the Physical Aspect of the Moon,—W R Birt Contribution to a Report on the Physical Aspect of the Moon,—Dr. Collingwood and Mr Byerley, Preliminary Report of the Dredging Committee of the Mersey and Dee —Third Report of the Committee on Steamship Performance —J G Jeffreys, Preliminary Report on the Best Mode of preventing the Ravages of *Teredo* and other Animals in our Ships and Harbours —R Mallet Report on the Experiments made at Holyhead to ascertain the Transit-Velocity of Waves analogous to Earthquake Waves through the local Rock Formations —T Dobson on the Explosions in British Coal Mines during the year 1859; —J Oldham Continuation of Report on Steam Navigation at Hull —Professor G Dickie, Brief Summary of a Report on the Flora of the North of Ireland,—Professor Owen, on the Psychical and Physical Characters of the Mincopies, or Natives of the Andaman Islands, and on the Relations thereby indicated to other Races of Mankind —Colonel Sykes, Report of the Balloon Committee Major-General Sabine, Report on the Repetition of the Magnetic Survey of England —Interim Report of the Committee for Dredging on the North and East Coasts of Scotland —W Fairbairn on the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities —W. Fairbairn Continuation of Report to determine the effect of Vibratory Action and long continued Changes of Load upon Wrought-Iron Girders,—Report of the Committee on the Law of Patents,—Prof H. J S Smith, Report on the Theory of Numbers Part III

Together with the Transactions of the Sections, Mr Fairbairn's Address, and Recommendations of the Association and its Committees

PROCEEDINGS of the THIRTY-SECOND MEETING, at Cambridge, October 1862, *Published at* £1.

Contents —James Glaisher, Report on Observations of Luminous Meteors, 1861–62;—G. B. Airy, on the Strains in the Interior of Beams,—Archibald Smith and F J. Evans, Report on the three Reports of the Liverpool Compass Committee,—Report on Tidal Observations on the Humber,—T Aston, on Rifled Guns and Projectiles adapted for Attacking Armour-plate Defences;—Extracts relating to the Observatory at Kew, from a Report presented to the Portuguese Government, by Dr J A de Souza;—H T Mennell, Report on the Dredging of the Northumberland Coast and Dogger Bank;—Dr Cuthbert Collingwood, Report upon the best means of advancing Science through the agency of the Mercantile Marine,—Messrs Williamson, Wheatstone, Thomson, Miller, Matthiessen, and Jenkin, Provisional Report on Standards of Electrical Resistance,—Preliminary Report of the Committee for investigating the Chemical and Mineralogical Composition of the Granites of Donegal;—Prof H. Hennessy, on the Vertical Movements of the Atmosphere considered in connexion with Storms and Changes of Weather;—Report of Committee on the application of Gauss's General Theory of Terrestrial Magnetism to the Magnetic Variations;—Fleeming Jenkin, on Thermo-electric Currents in Circuits of one Metal,—W. Fairbairn, on the Mechanical Properties of Iron Projectiles at High Velocities,—A Cayley, Report on the Progress of the Solution of certain Special Problems of Dynamics,—Prof G G Stokes, Report on Double Refraction,—Fourth Report of the Committee on Steamship Performance;—G J. Symons, on the Fall of Rain in the British Isles in 1860 and 1861,—J. Ball, on Thermometric Observations in the Alps,—J G. Jeffreys, Report of the Committee for Dredging on the N. and E. Coasts of Scotland,—Report of the Committee on Technical and Scientific Evidence in Courts of Law,—James Glaisher, Account of Eight Balloon Ascents in 1862,—Prof. H. J. S Smith, Report on the Theory of Numbers, Part IV.

Together with the Transactions of the Sections, the Rev Prof. R. Willis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-THIRD MEETING, at Newcastle-upon-Tyne, August and September 1863, *Published at* £1 5*s*.

Contents:—Report of the Committee on the Application of Gun-cotton to Warlike Purposes;—A Matthiessen, Report on the Chemical Nature of Alloys;—Report of the Committee on the Chemical and Mineralogical Constitution of the Granites of Donegal, and on the Rocks associated with them;—J G Jeffreys, Report of the Committee appointed for Exploring the Coasts of Shetland by means of the Dredge;—G. D. Gibb, Report on the Physiological Effects of the Bromide of Ammonium,—C K Aken, on the Transmutation of Spectral Rays, Part I,—Dr Robinson, Report of the Committee on Fog Signals,—Report of the Committee on Standards of Electrical Resistance,—E Smith, Abstract of Report by the Indian Government on the Foods used by the Free and Jail Populations in India;—A. Gages, Synthetical Researches on the Formation of Minerals, &c;—R. Mallet, Preliminary Report on the Experimental Determination of the Temperatures of Volcanic Foci, and of the Temperature, State of Saturation, and Velocity of the issuing Gases and Vapours;—Report of the Committee on Observations of Luminous Meteors,—Fifth Report of the Committee on Steamship Performance,—G J Allman, Report on the Present State of our Knowledge of the Reproductive System in the Hydroida;—J Glaisher, Account of Five Balloon Ascents made in 1863;—P. P Carpenter, Supplementary Report on the Present State of our Knowledge with regard to the Mollusca of the West Coast of North America;—Professor Airy, Report on Steam-boiler Explosions,—C. W. Siemens, Observations on the Electrical Resistance and Electrification of some Insulating Materials under Pressures up to 300 Atmospheres;—C. M. Palmer, on the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear, and Tees,—Messrs Richardson, Stevenson, and Clapham, on the Chemical Manufactures of the Northern Districts,—Messrs. Sopwith and Richardson, on the Local Manufacture of Lead, Copper, Zinc, Antimony, &c,—Messrs. Daglish and Forster, on the Magnesian Limestone of Durham;—I L Bell, on the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field,—T. Spencer, on the Manufacture of Steel in the Northern District,—H J. S Smith, Report on the Theory of Numbers, Part V.

Together with the Transactions of the Sections, Sir William Armstrong's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FOURTH MEETING, at Bath, September 1864, *Published* at 18*s*.

Contents:—Report of the Committee for Observations of Luminous Meteors;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—T. S Cobbold, Report of Experiments respecting the Development and Migration of the Entozoa;—B W Richardson, Report on the Physiological Action of Nitrite of Amyl;—J Oldham, Report of the Committee on Tidal Observations,—G. S. Brady, Report on deep-sea Dredging on the Coasts of Northumberland and Durham in 1864;—J. Glaisher, Account of Nine Balloon Ascents made in 1863 and 1864;—J G. Jeffreys, Further Report on Shetland Dredgings;—Report of the Committee on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report of the Committee on Standards of Electrical Resistance;—G J. Symons, on the Fall of Rain in the British Isles in 1862 and 1863;—W. Fairbairn, Preliminary Investigation of the Mechanical Properties of the proposed Atlantic Cable.

Together with the Transactions of the Sections, Sir Charles Lyell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIFTH MEETING, at Birmingham, September 1865, *Published at £1 5s.*

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Together with the Transactions of the Sections, Professor Phillips's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SIXTH MEETING, at Nottingham, August 1866, *Published at £1 4s*

CONTENTS —Second Report on Kent's Cavern, Devonshire,—A Matthiessen, Preliminary Report on the Chemical Nature of Cast Iron,—Report on Observations of Luminous Meteors;—W S Mitchell, Report on the Alum Bay Leaf-bed;—Report on the Resistance of Water to Floating and Immersed Bodies,—Dr. Norris, Report on Muscular Irritability;—Dr Richardson, Report on the Physiological Action of certain compounds of Amyl and Ethyl,—H. Woodward, Second Report on the Structure and Classification of the Fossil Crustacea;—Second Report on the "Menevian Group," and the other Formations at St. David's, Pembrokeshire,—J. G. Jeffreys, Report on Dredging among the Hebrides,—Rev. A M Norman, Report on the Coasts of the Hebrides, Part II;—J. Alder, Notices of some Invertebrata, in connexion with Mr Jeffreys's Report,—G. S Brady, Report on the *Ostracoda* dredged amongst the Hebrides,—Report on Dredging in the Moray Firth,—Report on the Transmission of Sound-Signals under Water;—Report of the Lunar Committee,—Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science;—J Glaisher, Account of Three Balloon Ascents;—Report on the Extinct Birds of the Mascarene Islands,—Report on the penetration of Iron-clad Ships by Steel Shot,—J. A. Wanklyn, Report on Isomerism among the Alcohols;—Report on Scientific Evidence in Courts of Law,—A L. Adams, Second Report on Maltese Fossiliferous Caves, &c

Together with the Transactions of the Sections, Mr. Grove's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SEVENTH MEETING, at Dundee, September 1867, *Published at £1 6s.*

CONTENTS:—Report of the Committee for Mapping the Surface of the Moon;—Third Report on Kent's Cavern, Devonshire,—On the present State of the Manufacture of Iron in Great Britain;—Third Report on the Structure and Classification of the Fossil Crustacea;—Report on the Physiological Action of the Methyl Compounds;—Preliminary Report on the Exploration of the Plant-Beds of North Greenland;—Report of the Steamship Performance Committee;—On the Meteorology of Port Louis in the Island of Mauritius;—On the Construction and Works of the Highland Railway;—Experimental Researches on the Mechanical Properties of Steel,—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall,—Supplement to a Report on the Extinct Didine Birds of the Mascarene Island —Report on Observations of Luminous Meteors,—Fourth Report on Dredging among the Shetland Isles,—Preliminary Report on the Crustacea, &c, procured by the Shetland Dredging Committee in 1867,—Report on the Foraminifera obtained in the Shetland Seas,—Second Report of the Rainfall Committee —Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science,—Report on Standards of Electrical Resistance

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PROCEEDINGS OF THE THIRTY EIGHTH MEETING, at Norwich, August 1868, *Published at* £1 5s

Contents —Report of the Lunar Committee,—Fourth Report on Kent's Cavern Devonshire,—On Puddling Iron,—Fourth Report on the Structure and Classification of the Fossil Crustacea,—Report on British Fossil Corals,—Report on Spectroscopic Investigations of Animal Substances, Report of Steamship Performance Committee —Spectrum Analysis of the Heavenly Bodies, On Stellar Spectrometry, —Report on the Physiological Action of the Methyl and allied Compounds —Report on the Action of Mercury on the Biliary Secretion,—Last Report on Dredging among the Shetland Isles, Reports on the Crustacea, &c, and on the Annelida and Foraminifera from the Shetland Dredgings, Report on the Chemical Nature of Cast Iron Part I, Interim Report on the Safety of Merchant Ships and their Passengers,—Report on Observations of Luminous Meteors —Preliminary Report on Mineral Veins containing Organic Remains Report on the desirability of Explorations between India and China, Report of Rainfall Committee, Report on Synthetical Researches on Organic Acids, Report on Uniformity of Weights and Measures,—Report of the Committee on Tidal Observations —Report of the Committee on Underground Temperature,—Changes of the Moon's Surface, Report on Polyatomic Cyanides

Together with the Transactions of the Sections Dr Hooker's Address, and Recommendations of the Association and its Committees

PROCEEDINGS OF THE THIRTY-NINTH MEETING, at Exeter, August 1869, *Published* at £1 2s

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Together with the Transactions of the Sections, Prof Stokes's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTIETH MEETING, at Liverpool, September 1870, *Published at* 18s

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Together with the Transactions of the Sections, Prof Huxley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIRST MEETING, at Edinburgh, August 1871, *Published at* 16s

CONTENTS —Seventh Report on Kent s Cavern,—Fourth Report on Underground Temperature,—Report on Observations of Luminous Meteors 1870 71 —Fifth Report on the Structure and Classification of the Fossil Crustacea,—Report for the purpose of urging on Her Majesty's Government the expediency of arranging and tabulating the results of the approaching Census in the three several parts of the United Kingdom in such a manner as to admit of ready and effective comparison;—Report for the purpose of Superintending the publication of Abstracts of Chemical papers,—Report of the Committee for discussing Observations of Lunar Objects suspected of change, Second Provisional Report on the Thermal Conductivity of Metals,—Report on the Rainfall of the British Isles,—Third Report on the British Fossil Corals,—Report on the Heat generated in the Blood during the process of Arterialization,—Report of the Committee appointed to consider the subject of physiological Experimentation,—Report on the Physiological Action of Organic Chemical Compounds,—Report of the Committee appointed to get cut and prepared Sections of Mountain Limestone Corals,—Second Report on Steam Boiler Explosions,—Report on the Treatment and Utilization of Sewage —Report on promoting the Foundation of Zoological Stations in different parts of the World,—Preliminary Report on the Thermal Equivalents of the Oxides of Chlorine,—Report on the practicability of establishing a Close Time" for the protection of Indigenous Animals,—Report on Earthquakes in Scotland, Report on the best means of providing for a Uniformity of Weights and Measures,—Report on Tidal Observations

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PROCEEDINGS OF THE FORTY-SECOND MEETING, at Brighton, August 1872, *Published at* £1 4s

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Together with the Transactions of the Sections, Dr Carpenter s Address, and Recommendations of the Association and its Committees

PROCEEDINGS OF THE FORTY-THIRD MEETING, at Bradford, September 1873 *Published at* £1 5s

Contents —Report of the Committee on Mathematical Tables —Observations on the Application of Machinery to the cutting of Coal in Mines —Concluding Report on the Maltese Fossil Elephants —Report of the Committee for ascertaining the existence in different parts of the United Kingdom of any Erratic Blocks or Boulders —Fourth Report on Earthquakes in Scotland —Ninth Report on Kent s Cavern —On the Flint and Chert Implements found in Kent s Cavern, Report of the Committee for investigating the Chemical Constitution and Optical Properties of Essential Oils —Report of inquiry into the Method of making Gold assays —Fifth Report on the Selection and Nomenclature of Dynamical and Electrical Units —Report of the Committee on the Labyrinthodonts of the Coal measures,—Report of the Committee to construct and print Catalogues of Spectral Rays —Report of the Committee appointed to explore the Settle Caves —Sixth Report on Underground Temperature,—Report on the Rainfall of the British Isles —Seventh Report on Researches in Fossil Crustacea —Report on Recent Progress in Elliptic and Hyperelliptic Functions,—Report on the desirability of establishing a Close Time for the preservation of indigenous animals —Report on Luminous Meteors —On the visibility of the dark side of Venus,—Report of the Committee for the foundation of Zoological Stations in different parts of the world —Second Report of the Committee for collecting Fossils from North western Scotland —Fifth Report on the Treatment and Utilization of Sewage —Report of the Committee on Monthly Reports of the Progress of Chemistry —On the Bradford Waterworks,—Report on the possibility of Improving the Methods of Instruction in Elementary Geometry;—Interim Report of the Committee on Instruments for Measuring the Speed of Ships &c;—Report of the Committee for Determinating High Temperatures by means of the Refrangibility of Light, evolved by Fluid or Solid Substances —On a periodicity of Cyclones and Rainfall in connexion with Sun spot periodicity —Fifth Report on the Structure of Carboniferous Limestone Corals —Report of the Committee on preparing and publishing brief forms of Instructions for Travellers, Ethnologists, &c —Preliminary Note from the Committee on the Influence of Forests on the Rainfall —Report of Sub Wealden Exploration Committee,—Report of the Committee on Machinery for obtaining a Record of the Roughness of the Sea and Measurement of Waves near shore,—Report on Science-Lectures and Organization,—Second Report on Science Lectures and Organization

Together with the Transactions of the Sections Professor A W Williamson's Address, and Recommendations of the Association and its Committees

PROCEEDINGS OF THE FORTY-FOURTH MEETING, at Belfast, August 1874, *Published at* £1 5s

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of certain Rocks,—Second Report on the Exploration of the Settle Caves,—On the Industrial uses of the Upper Bann river,—Report of the Committee on the Structure and Classification of the Labyrinthodonts,—Second Report of the Committee for recording the position, height above the sea, lithological characters, size and origin of the Erratic Blocks of England and Wales, &c —Sixth Report on the Treatment and Utilization of Sewage,—Report on the Anthropological Notes and Queries for the use of Travellers —On Cyclone and Rainfall Periodicities,—Fifth Report on Earthquakes in Scotland Report of the Committee to prepare and print Tables of Wave numbers —Report of the Committee for testing the new Pyrometer of Mr Siemens Report to the Lords Commissioners of the Admiralty on Experiments for the Determination of the Frictional Resistance of Water on a Surface &c —Second Report for the Selection and Nomenclature of Dynamical and Electrical Units On Instruments for measuring the Speed of Ships,—Report of the Committee on the possibility of establishing a "Close time" for the Protection of Indigenous Animals —Report of the Committee to inquire into the economic effects of Combinations of Labourers and Capitalists —Preliminary Report on Dredging on the Coasts of Durham and North Yorkshire —Report on Luminous Meteors —Report on the best means of providing for a Uniformity of Weights and Measures

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PROCEEDINGS OF THE FORTY-FIFTH MEETING, at Bristol, August 1875, *Published at £1 5s*

Contents —Eleventh Report on Kent's Cavern —Seventh Report on Underground Temperature,—Report on the Zoological Station at Naples, Report of a Committee to inquire into the Methods employed in the estimation of Potash and Phosphoric Acid in Commercial Products Report on the present state of our knowledge of the Crustacea, Second Report on the Thermal Conductivities of certain Rocks, Preliminary Report for extending the observations on the Specific Volumes of Liquids —Sixth Report on Earthquakes in Scotland —Seventh Report on the Treatment and Utilization of Sewage,—Report of the Committee for furthering the Palestine Explorations —Third Report of the Committee for recording the position, height above the sea lithological characters, size and origin of the Erratic Blocks of England and Wales, &c —Report of the Rainfall Committee,—Report of the Committee for investigating Isomeric Cresols and their Derivatives,—Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England,—On the Steering of Screw Steamers Second Report of the Committee on Combinations of Capital and Labour;—Report of inquiry into the Method of making Gold assays —Eighth Report on Underground Temperature —Tides in the River Mersey —Sixth Report of the Committee on the Structure of Carboniferous Corals —Report of the Committee appointed to explore Settle Caves,—On the River Avon (Bristol) its Drainage Area &c —Report of the Committee on the possibility of establishing a Close time for the Protection of Indigenous Animals,—Report of the Committee appointed to superintend the Publication of the Monthly Reports of the Progress of Chemistry,—Report on Dredging off the Coast of Durham and North Yorkshire in 1874 —Report on Luminous Meteors On the Analytical Forms called Trees —Report of the Committee on Mathematical Tables,—Report of the Committee on Mathematical Notation and Printing;—Second Report of the Committee for investigating Intestinal Secretion,—Third Report of the Sub Wealden Exploration Committee

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FOR

THE ADVANCEMENT OF SCIENCE.

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1877.

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1873 ‡Ackroyd, Samuel Greaves street, Little Horton, Bradford, Yorkshire
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Adair, John 13 Merrion-square North Dublin
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Year of Election

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Allan, William.

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1861 †Allen, Richard. Didsbury, near Manchester.

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1863 ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.

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1875 §Alston, Edward R., F.Z.S. 22A Dorset-street, Portman-square, London, W.

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1868 *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.

1860 *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.

1857 ‡Barker, John, M.D., Curator of the Royal College of Surgeons of Ireland. Waterloo-road, Dublin.

1865 ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.

1870 ‡BARKLY, Sir HENRY, K.C.B., F.R.S., F.R.G.S., Governor of Cape Colony and Dependencies. Cape of Good Hope.

1873 ‡Barlow, Crawford, B.A. 2 Old Palace-yard, Westminster, S.W.

Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.

Barlow, Peter. 5 Great George-street, Dublin.

1857 ‡BARLOW, PETER WILLIAM, F.R.S., F.G.S. 26 Great George-street, Westminster, S.W.

1873 ‡BARLOW, W. H., C.E., F.R.S. 2 Old Palace-yard, Westminster, S.W.

1861 *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.

1868 §Barnes, Richard H. (Care of Messrs. Collyer, 4 Bedford-row, London, W.C.)

Year of Election

Barnes, Thomas Addison 40 Chester-street, Wrexham
*Barnett, Richard, M R C S 2 Barbourne-terrace, Worcester
1859 ‡Barr, Major-General, Bombay Army Culter House, near Aberdeen (Messrs Forbes, Forbes & Co, 9 King William-street, London)
1861 *Barr, William R, F G S Fernside, Cheadle Hulme, Cheshire
1860 ‡Barrett T B High-street, Welshpool, Montgomery
1872 *BARRETT, Professor W F, F R S E, M R I A, F C S Royal College of Science, Dublin
1852 ‡Barrington Edward Fassaroe, Bray, Co Wicklow
1874 ‡Barrington R M Fassaroe, Bray Co Wicklow
1874 §Barrington-Ward Mark J, M A, F L S, F R G S, H M Inspector of Schools St Winifred's, Lincoln
1866 ‡Barron, William Elvaston Nurseries, Borrowash, Derby
1858 ‡BARRY, Rev Canon, D D, D C L, Principal of King's College, London, W C
1862 *Barry, Charles 15 Pembridge-square, Bayswater, London, W
1875 ‡Barry John Wolfe 23 Delahay-street, Westminster, S W
Barstow, Thomas Garrow-hill, near York
1858 *Bartholomew Charles Castle hill House, Ealing, Middlesex, W
1855 ‡Bartholomew, Hugh New Gas-works, Glasgow
1858 *Bartholomew, William Hammond Ridgeway House, Cumberland-road, Headingley, Leeds
1873 §Bartley, George C T Ealing, Middlesex, W
1868 *Barton Edward (27th Inniskillens) Clonelly, Ireland
1857 ‡Barton Folliott W Clonelly, Co Fermanagh
1852 ‡Barton, James Farndreg, Dundalk
1864 ‡Bartrum, John S 41 Gay street, Bath
*Bashforth, Rev Francis, B D Minting Vicarage, near Horncastle
1861 ‡Bass, John H F G S 287 Camden-road, London, N
1876 §Bassano, Alexander 12 Montagu place, London, W
1876 §Bassano Clement Jesus College Cambridge
1866 *BASSETT HENRY 44 St Paul's-road, Camden-square, London, N W
1866 ‡Bassett, Richard Pelham street, Nottingham
1869 ‡Bastard, S S Summerland-place, Exeter
1871 ‡BASTIAN, H CHARLTON, M A, M D, F R S, F L S, Professor of Pathological Anatomy at University College Hospital 20 Queen Anne street London, W
1848 ‡BATE, C SPENCE, F R S, F L S 8 Mulgrave-place, Plymouth
1873 *Bateman, Daniel Low Moor near Bradford, Yorkshire
1868 ‡Bateman, Frederick M D Upper St Giles's-street, Norwich,
BATEMAN, JAMES M A, F R S, F R G S, F L S 9 Hyde Park-gate South, London, W
1842 *BATEMAN, JOHN FREDERIC, C E, F R S, F G S, F R G S 16 Great George-street, London, S W
1864 ‡BATES, HENRY WALTER, Assist-Sec R G S, F L S 1 Savile-row, London, W
1852 ‡Bateson, Sir Robert, Bart Belvoir Park, Belfast
1851 ‡BATH AND WELLS, Lord ARTHUR HERVEY, Lord Bishop of The Palace, Wells Somerset
1863 *Bathurst, Rev W H Lydney Park, Gloucestershire
1869 ‡Batten, John Winterbotham 35 Palace-gardens-terrace, Kensington, London, S W
1863 §JAUERMAN, H, F G S 22 Acre-lane, Brixton, London, S W.
1861 ‡Baxendell, Joseph, F R A S 108 Stock-street, Manchester
1867. ‡Baxter, Edward. Hazel Hall, Dundee

Year of Election.

1867. ‡Baxter, John B Craig Tay House, Dundee

1867. ‡Baxter, William Edward, M P. Ashcliffe, Dundee.

1868. ‡Bayes, William, M D 58 Brook-street, London, W.

1851. *Bayley, George. 16 London-street, Fenchurch-street, London, E C

1866. ‡Bayley, Thomas Lenton, Nottingham

1854. ‡Baylis, C O, M D. 22 Devonshire-road, Claughton, Birkenhead.

Bayly, John. Seven Trees, Plymouth

1875 *Bayly, Robert. Torr-grove, near Plymouth

1876. *Baynes, Robert E, M A Christ Church, Oxford

Bazley, Thomas Sebastian, M A. Hatherop Castle, Fairford, Gloucestershire

1860 *BEALE, LIONEL S, M D, F R S, Professor of Pathological Anatomy in King's College 61 Grosvenor-street, London, W

1872 ‡Beanes, Edward, F C S. The White House, North Dulwich, Surrey, S E

1870. ‡Beard, Rev Charles. 13 South-hill-road, Toxteth Park, Liverpool

*Beatson, William Chemical Works, Rotherham

1855. *Beaufort, W. Morris, F R A S, F R G S, F M S, F S S. Athenæum Club, Pall Mall, London, S W

1861 *Beaumont, Rev Thomas George Chelmondiston Rectory, Ipswich

1871. *Beazley, Captain George G, F.R G S Army and Navy Club, Pall Mall, London, S W

1859 *Beck, Joseph, F R A S 31 Cornhill, London, E C

1864. §Becker, Miss Lydia E Whalley Range, Manchester

1860. ‡BECKLES, SAMUEL H, F R S, F G S 9 Grand-parade, St Leonard's-on-Sea.

1866 ‡Beddard, James Derby-road, Nottingham

1870. §BEDDOE, JOHN, M D, F R S Clifton, Bristol

1873. ‡Behrens, Jacob Springfield House, North-parade, Bradford

1865. *BELAVENETZ, I, Captain of the Russian Imperial Navy, F R I G S, M.S C.M A., Superintendent of the Compass Observatory, Cronstadt. (Care of Messrs Baring Brothers, Bishopsgate-street, London, E C)

1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.

1873. §Bell, A P. Royal Exchange, Manchester

1871. §Bell, Charles B 6 Spring-bank, Hull

Bell, Frederick John. Woodlands, near Maldon, Essex.

1859. ‡Bell, George Windsor-buildings, Dumbarton.

1860. ‡Bell, Rev. George Charles, M A Christ's Hospital, London, E C

1855. ‡Bell, Capt Henry Chalfont Lodge, Cheltenham.

1862. *BELL, ISAAC LOWTHIAN, M P, F R S, F C S., M.I C.E. The Hall, Washington, Co Durham

1875. §Bell, James, F.C.S. The Laboratory, Somerset House, London, W C.

1871. *Bell, J Carter, F C S. Kersal Clough, Higher Broughton, Manchester.

1853. ‡Bell, John Pearson, M D. Waverley House, Hull.

1864. ‡Bell, R. Queen's College, Kingston, Canada.

1876. §Bell, R. Bruce. 2 Clifton-place, Glasgow

BELL, THOMAS, F.R.S., F L.S, F.G.S. The Wakes, Selborne, near Alton, Hants.

1863. *Bell, Thomas. The Minories, Jesmond, Newcastle-on-Tyne.

1867. ‡Bell, Thomas. Belmont, Dundee.

1875. ‡Bell, William 86 Park-road, New Wandsworth, Surrey, S.W.

1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.

Year of
Election.

1854 ‡*Bellhouse, William Dawson 1 Park-street, Leeds*
Bellingham, Sir Alan Castle Bellingham, Ireland
1856 *BELPER, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.G.S. 75 Eaton-square, London, S.W., and Kingston Hall, Derby.
1864 **Bendyshe, T. 13 Buckingham-street, Strand, London, W.C.*
1870 ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1871 ‡Bennett, F. J. 12 Hillmarten-road, Camden-road, London, N.
1870 *Bennett, William 109 Shaw-street, Liverpool
1870 *Bennett, William, jun. Oak Hill Park, Old Swan, near Liverpool.
1852 *Bennoch, Francis, F.S.A. 19 Tavistock-square, London, W.C.
1857 ‡Benson, Charles 11 Fitzwilliam-square West, Dublin
Benson, Robert, jun. Fairfield, Manchester
1848 ‡Benson, Starling, F.G.S. Gloucester-place, Swansea
1870 ‡Benson, W. Alresford, Hants
1863 ‡Benson, William Fourstones Court, Newcastle-on-Tyne
1848 ‡BENTHAM, GEORGE, F.R.S., F.R.G.S., F.L.S. 25 Wilton-place, Knightsbridge, London, S.W.
1842 Bentley, John 9 Portland-place, London, W.
1863 §BENTLEY, ROBERT, F.L.S., Professor of Botany in King's College. 91 Alexandra-road, St. John's Wood, London, N.W.
1875 ‡*Beor, Henry R. 3 Harcourt-buildings, Temple, London, E.C.*
1876 §Bergius, Walter C. 9 Loudon-terrace, Hillhead, Glasgow
1868 ‡BERKELEY, Rev. M. J., M.A., F.L.S. Sibbertoft, Market Harborough
1863 ‡Berkley, C. Marley Hill, Gateshead, Durham
1848 ‡Berrington, Arthur V. D. Woodlands Castle, near Swansea
1866 ‡Berry, Rev. Arthur George Monyash Parsonage, Bakewell, Derbyshire
1870 ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland
1862 ‡Besant, William Henry, M.A., F.R.S. St. John's College, Cambridge.
1865 *BESSEMER, HENRY Denmark Hill, Camberwell, London, S.E.
1858 ‡Best, William Leydon-terrace, Leeds
Bethune, Admiral, C.B., F.R.G.S. Balfour, Fifeshire.
1876 §Bettany, G. T., B.A., B.Sc. Caius College, Cambridge.
1859 ‡Beveridge, Robert, M.B. 36 King-street, Aberdeen
1874 *Bevington, James B. Merle Wood, Sevenoaks
1863 ‡Bewick, Thomas John, F.G.S. Haydon Bridge, Northumberland
*Bickerdike, Rev. John, M.A. St. Mary's Vicarage, Leeds
1870 ‡Bickerton, A. W., F.C.S. Hartley Institution, Southampton
1868 ‡BIDDER, GEORGE PARKER, C.E., F.R.G.S. 24 Great George-street, Westminster, S.W.
1863 ‡Bigger, Benjamin Gateshead, Durham
1864 ‡Biggs, Robert 17 Charles-street, Bath
1855. ‡*Billings, Robert William 4 St. Mary's-road, Canonbury, London, N.*
Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.
1842. BINNEY, EDWARD WILLIAM, F.R.S., F.G.S. Cheetham Hill, Manchester
1873. ‡Binns, J. Arthur Manningham, Bradford, Yorkshire.
Birchall, Edwin Airedale Cliff, Newley, Leeds.
Birchall, Henry College House, Bradford
1866. *Birkin, Richard Aspley Hall, near Nottingham
*Birks, Rev. Thomas Rawson, M.A., Professor of Moral Philosophy in the University of Cambridge. 7 Brookside, Cambridge.
1841. *BIRT, WILLIAM RADCLIFF, F.R.A.S. Hawkenbury, Palmerston-road, Buckhurst Hill.

Year of Election.

1871 *BISCHOF, GUSTAV 4 Hart-street, Bloomsbury, London, W C
1868 ‡Bishop, John Thorpe Hamlet, Norwich
1868 ‡Bishop, Thomas Bramcote, Nottingham
1869 ‡Blackall, Thomas 13 Southernhay Exeter
1876 §Blackburn, Hugh, M A, Professor of Mathematics in the University of Glasgow
Blackburne, Rev John, M A Yarmouth Isle of Wight
Blackburne, Rev John, jun, M A Rectory, Horton, near Chippenham
1850 ‡Blackie, John Stewart, M A Professor of Greek in the University of Edinburgh
1876 §Blackie Robert 7 Great Western-terrace, Glasgow
1855 *BLACKIE, W G Ph D F R G S 17 Stanhope-street Glasgow
1870 ‡Blackmore, W 1 Founders'-court Lothbury London E C
*BLACKWALL Rev JOHN, F L S Hendre House, near Llanrwst, Denbighshire
1863 ‡Blake, C Carter, Ph D, F G S Westminster Hospital School of Medicine Broad Sanctuary Westminster S W
1849 *BLAKE HENRY WOLLASTON M A, F R S F R G S 8 Devonshire-place Portland-place London, W
1846 *Blake, William Bridge House South Petherton Somerset
1845 ‡*Blakesley, Rev J W B D Ware Vicarage, Hertfordshire*
1861 §Blakiston, Matthew F R G S 18 Wilton-crescent, London S W
*Blakiston Peyton M D F R S 140 Harley-street London W
1868 ‡*Blanc, Henry M D 9 Bedford-street, Bedford-square London, W*
1869 ‡Blanford, W T F R S, F G S F R G S Geological Survey of India, Calcutta (12 Keppel-street Russell-square, London W C)
*BLOMEFIELD, Rev LEONARD, M A, F L S, F G S 19 Belmont, Bath
Blore, Edward, LL D F R S F R G S, F S A 4 Manchester-square, London, W
1870 ‡Blundell Thomas Weld Ince Blundell Hall, Great Crosby, Lancashire
1859. ‡Blunt, Sir Charles Bart Heathfield Park Sussex
1859 ‡Blunt, Capt Richard Bretlands Chertsey Surrey
Blyth, B Hall 135 George-street Edinburgh
1858 *Blythe, William Holland Bank, Church near Accrington
1870 ‡Boardman, Edward Queen-street, Norwich
1845 ‡*Bodmer, Rodolph*
1866 §Bogg, Thomas Wemyss Louth Lincolnshire
1876. §Bogue, David 192 Piccadilly, London W
1850 *BOHN, HENRY G, F L S F R A S, F R G S, F S S North End House, Twickenham
1871 §Bohn, Mrs North End House, Twickenham
1859 ‡Bolster, Rev Prebendary John A Cork
1876 §Bolton, J C Carbrook Stirling
Bolton, R L Laurel Mount, Aigburth-road, Liverpool
1866 ‡Bond, Banks Low Pavement, Nottingham
1863. ‡*Bond, Francis T, M D*
Bond, Henry John Hayes, M D Cambridge
1871. §Bonney, Rev Thomas George, M A, F S A, F G S St John's College, Cambridge
Bonomi, Ignatius 36 Blandford-square, London, N W
BONOMI, JOSEPH Soane's Museum, 15 Lincoln's-Inn-fields, London, W C
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. §Booth, James. Elmfield, Rochdale

Year of Election.

1835 ‡Booth, Rev James LL D, F R S, F R A S, F R G S The Vicarage Stone near Aylesbury

1861 *Booth William Hollybank Cornbrook Manchester

1876 §Booth William H Trinity College Oxford

1861 *Borchardt Louis, M D Barton Arcade Manchester

1849 ‡Boreham, William W F R A S The Mount Haverhill Newmarket

1870 *Borland William 5 Annfield place Glasgow

1863 ‡Borries Theodore Lovaine crescent Newcastle on-Tyne

1876 *Bosanquet, R H M, M A F C S F R A S St John's College, Oxford

*Bossey Francis M D Mayfield Oxford road Redhill Surrey

1867 §Botly, William, F S A Salisbury House Hamlet road, Upper Norwood London S E

1858 ‡Botterill John Burley near Leeds

1872 ‡Bottle, Alexander Dover

1868 ‡Bottle J T 28 Nelson road Great Yarmouth

1871 ‡BOTTOMLEY, JAMES THOMSON, M A F C S The College, Glasgow

Bottomley William 14 Brunswick gardens Kensington, London, W

1876 §Bottomley William, jun 14 Brunswick gardens Kensington, London W

1850 ‡Bouch Thomas C E Oxford terrace Edinburgh

1870 ‡Boult Swinton 1 Dale street, Liverpool

1868 ‡Boulton W S Norwich

1866 §Bourne, Stephen F S S Abberley Lodge Hudstone drive Harrow

1872 ‡Bovill William Edward 29 James street, Buckingham gate, London S W

1870 ‡Bower, Anthony Bowerdale Seaforth Liverpool

1867 ‡Bower Dr John Perth

1856 *Bowlby, Miss F E 27 Lansdown crescent Cheltenham

1863 ‡Bowman R Benson Newcastle on Tyne

Bowman William F R S F R C S 5 Clifford street, London, W

1869 ‡Bowring Charles T Elm leigh Princes Park, Liverpool

18[illegible] ‡*Bowring J C Larkbeare Exeter*

1863 ‡Bowron James South Stockton on Tees

1863 §Boyd Edward Fenwick Moor House near Durham

1871 ‡Boyd, Thomas J 41 Moray place Edinburgh

1865 ‡BOYLE, Rev G D Soho House Handsworth, Birmingham

1872 *BRABROOK E W F S A, Dir A I 28 Abingdon-street, Westminster S W

1869 *Braby Frederick F G S F C S Mount Henley, Sydenham Hill, London S E

1870 §Brace Edmund 3 Exchange-square Glasgow

Bracebridge Charles Holt, F R G S The Hall Atherstone, Warwickshire

1861 *Bradshaw William Slade House, Green walk, Bowdon, Cheshire

1842 *BRADY, Sir ANTONIO J P, F G S Maryland Point, Stratford, Essex, E

1857 *Brady, Cheyne, M R I A Four Courts, Co Dublin

Brady Daniel F M D 5 Gardiner's-row, Dublin

1863 ‡BRADY, GEORGE S 22 Fawcett-street, Sunderland

1862 §BRADY, HENRY BOWMAN, F R S, F L S, F G S 29 Mosley-street, Newcastle-on-Tyne

1858 ‡*Brae Andrew Edmund*

1875 ‡Bragge, William, F S A, F G S Shirle Hill, Sheffield

Year of Election.

1864 §Braham, Philip, F C S 6 George-street, Bath
1870 §Braidwood, Dr Delemere-terrace, Birkenhead
1864 §Braikenridge, Rev George Weare, M A, F L S Clevedon, Somerset
1865 §BRAMWELL, FREDERICK J, M I C E, F R S 37 Great George-street, London, S W
1872 ‡Bramwell, William J 17 Prince Albert-street, Brighton
Brancker, Rev Thomas, M A Limington, Somerset
1867 ‡Brand, William Milnefield, Dundee
1861 *Brandreth Rev Henry Dickleburgh Rectory, Scole, Norfolk
1852 ‡BRAZIER, JAMES S, F C S, Professor of Chemistry in Marischal College and University of Aberdeen
1857 ‡Brazill, Thomas 12 Holles-street Dublin
1860 *BREADALBANE The Right Hon the Earl of Taymouth Castle, N B, and Carlton Club, Pall Mall, London, S W
1873 §Breffit Edgar Castleford, near Normanton
1868 ‡Bremridge, Elias 17 Bloomsbury-square, London, W C
1869 †Brent, Colonel Robert Woodbury, Exeter
1860 ‡Brett, G Salford
1866 ‡Brettell, Thomas (Mine Agent) Dudley
1865 §Brewin, William Cirencester
1875 §Briant T Hampton Wick, Kingston-on Thames
1867 ‡BRIDGMAN, WILLIAM KENCELEY 69 St Giles's street, Norwich
1870 *Bridson, Joseph R Belle Isle, Windermere
1870 ‡Brierley, Joseph, C E New Market street, Blackburn
1870 *BRIGG, JOHN Broomfield, Keighley, Yorkshire
1866 *Briggs, Arthur Cragg Royd, Rawdon, near Leeds
1866 §Briggs, Joseph Barrow-in-Furness
1863 *BRIGHT Sir CHARLES TILSTON C E, F G S, F R G S, F R A S 20 Bolton-gardens London, S W
1870 ‡Bright, H A M A, F R G S Ashfield, Knotty Ash
BRIGHT The Right Hon JOHN, M P Rochdale, Lancashire
1868 ‡BRINE, Commander LINDESAY Army and Navy Club, Pall Mall, London, S W
1842 Broadbent, Thomas Marsden-square, Manchester
1859 *BRODHURST, BERNARD EDWARD 20 Grosvenor-street, Grosvenor-square, London, W
1847 ‡BRODIE, Sir BENJAMIN C, Bart, M A, D C L, F R S, F C S Brockham Warren, Reigate
1834 ‡BRODIE, Rev JAMES, F G S Monimail, Fifeshire
1865 ‡BRODIE, Rev PETER BELLINGER, M A, F G S Rowington Vicarage, near Warwick
1853 †Bromby, J H, M A The Charter House Hull
*BROOKE, CHARLES, M A, F R S, F R C S 16 Fitzroy-square, London, W
1855 ‡Brooke, Edward Marsden House, Stockport, Cheshire
1864 *Brooke, Rev J Ingham Thornhill Rectory, Dewsbury
1855 ‡Brooke, Peter William Marsden House, Stockport, Cheshire
1863 §Brooks, John Crosse Wallsend, Newcastle-on-Tyne
1846. *Brooks, Thomas Cranshaw Hall, Rawstenstall, Manchester
Brooks, William Ordfall Hill, East Retford, Nottinghamshire.
1874 §Broom, William 20 Woodlands-terrace, Glasgow
1847 ‡Broome, C Edward, F L S Elmhurst, Batheaston, near Bath
1863 *Brough, Lionel H, F G S, one of Her Majesty's Inspectors of Coal-Mines 11 West Mall, Clifton, Bristol
*BROUN, JOHN ALLAN, F R S 4 Abercorn-place, St John's Wood, London, N W
1864 ‡Brown, Mrs. 1 Stratton-street, Piccadilly, London, W.

Year of
Election

1863 *BROWN, ALEXANDER CRUM, M.D., F.R.S.E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.

1867 ‡Brown, Charles Gage, M.D. 88 Sloane-street, London, S.W.

1855 ‡Brown, Colin. 192 Hope-street, Glasgow.

1871 §Brown, David. 93 Abbey-hill, Edinburgh.

1863 *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.

1868 §Brown, Henry, J.P., LL.D. Daisy Hill, Rawdon, Leeds.

1870 §BROWN, HORACE T. The Bank, Burton-on-Trent.

Brown, Hugh. Broadstone, Ayrshire.

1870 *BROWN, J. CAMPBELL, D.Sc., F.C.S. Royal Infirmary School of Medicine, Liverpool.

1876 §Brown, John. Edenderry House, Belfast.

1859 †Brown, Rev. John Crombie, LL.D., F.L.S. Berwick-on-Tweed.

1863 †*Brown, John H.*

1874 †Brown, John S. Edenderry, Shaw's Bridge, Belfast.

1863 ‡Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.

1871 ‡BROWN, ROBERT, M.A., Ph.D., F.L.S., F.R.G.S. 26 Guildford-road, Albert-square, London, S.W.

1868 ‡Brown, Samuel. Grafton House, Swindon, Wilts.

**Brown, Thomas. Guentland, Chepstow.*

*Brown, William. 11 Maiden-terrace, Dartmouth Park, London, N.

1855 †Brown, William. Berkeley-terrace, Glasgow.

1850 ‡Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.

1865 †Brown, William. 41 New-street, Birmingham.

1866 *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.

1862 *Browne, Robert Clayton, jun., B.A. Browne's Hill, Carlow, Ireland.

1872 ‡Browne, R. Mackley, F.G.S. Northside, St. John's, Sevenoaks, Kent.

1875 †Browne, Walter R. Bridgwater.

1865 *Browne, William, M.D. The Friary, Lichfield.

1865 †Browning, John, F.R.A.S. 111 Minories, London, E.

1855 §Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.

1853 †Brownlow, William B. Villa-place, Hull.

1863 *Brunel, H. M. 23 Delahay-street, Westminster, S.W.

1863. ‡Brunel, J. 23 Delahay-street, Westminster, S.W.

1875 *Brunlees, James, C.E., F.G.S. 5 Victoria-street, Westminster, S.W.

1875 §Brunlees, John. 5 Victoria-street, Westminster, S.W.

1871 †*Brunnow, F.*

1868 †BRUNTON, T. LAUDER, M.D., F.R.S. 23 Somerset-street, Portman-square, London, W.

1877 §Bryant, George. India Office, London, S.W.

1875 ‡Bryant, G. Squier. 15 White Ladies-road, Clifton, Bristol.

1875 §Bryant, Miss S. A. The Castle, Denbigh.

1861 †Bryce, James. York Place, Higher Broughton, Manchester.

BRYCE, JAMES, M.A., LL.D., F.R.S.E., F.G.S. 18 Morningside-place, Edinburgh.

BRYCE, Rev. R. J., LL.D., Principal of Belfast Academy. Belfast.

1859 ‡Bryson, William Gillespie. Cullen, Aberdeen.

1867 ‡BUCCLEUCH and QUEENSBERRY, His Grace the Duke of, K.G., D.C.L., F.R.S.L. & E., F.L.S. Whitehall-gardens, London, S.W.; and Dalkeith House, Edinburgh.

1871. §BUCHAN, ALEXANDER, M.A., F.R.S.E., Sec. Scottish Meterological Society. 72 Northumberland-street, Edinburgh.

1867 ‡Buchan, Thomas. Strawberry Bank, Dundee.

BUCHANAN, ANDREW, M.D., Professor of the Institutes of Medicine in the University of Glasgow. 4 Ethol-place, Glasgow.

Year of Election

Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D C. Poulton cum Seacombe, Cheshire.
1871 ‡Buchanan, John Y 10 Moray-place, Edinburgh
1864. §BUCKLE, Rev GEORGE, M A Twerton Vicarage, Bath
1865. *Buckley, Henry 27 Wheeley's-road, Edgbaston, Birmingham
1848. *BUCKMAN, Professor JAMES, F L S , F G S Bradford Abbas, Sherborne, Dorsetshire
1860. ‡Bucknill, J C , M D , F.R S 39 Wimpole-street, London, W.
1851 *BUCKTON, GEORGE BOWDLER, F R S , F L S , F C S. Weycombe, Haslemere, Surrey
1848 *BUDD, JAMES PALMER Ystalyfera Iron Works, Swansea
1875 §Budgett, Samuel Cotham House, Bristol
1871. §Bulloch, Matthew 11 Park-circus, Glasgow.
1845. *BUNBURY, Sir CHARLES JAMES FOX, Bart , F R S , F L S , F G S , F R G S Barton Hall, Bury St Edmunds
1865 ‡Bunce, John Mackray 'Journal Office,' New-street, Birmingham.
1863 §Bunning, T Wood Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne
1842. *Burd, John 5 Gower-street, London, W C
1875 ‡Burder, John, M D. 7 South Parade, Bristol.
1869. ‡Burdett-Coutts, Baroness Stratton-street, Piccadilly, London, W.
1874 ‡Burdon, Henry, M D Clandeboye, Belfast
1872. *Burgess, Herbert 62 High-street, Battle, Sussex
1857. ‡*Burk, J Lardner, LL D*
1865. ‡*Burke, Luke 5 Albert Terrace, Acton, London, W.*
1869. **Burnell, Arthur Coke*
1876. §Burnet, John 14 Victoria-crescent, Dowanhill, Glasgow
1859. ‡Burnett, Newell Belmont-street, Aberdeen
1860 ‡Burrows, Montague, M A , Professor of Modern History, Oxford.
1874 §Burt, Rev. J T Broadmoor, Berks
1866 *BURTON, FREDERICK M , F G S Highfield, Gainsborough
1864. ‡Bush, W 7 Circus, Bath
Bushell, Christopher Royal Assurance-buildings, Liverpool
1855. *BUSK, GEORGE, F R S , V P L S , F G S 32 Harley-street, Cavendish-square, London, W
1857 ‡Butt, Isaac, Q C , M P. 64 Eccles-street, Dublin
1855. *Buttery, Alexander W Cardarroch House, near Airdrie.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk
1870. ‡Buxton, David, Principal of the Liverpool Deaf and Dumb Institution, Oxford-street, Liverpool.
1868 ‡Buxton, S Gurney Catton Hall, Norwich
1872. ‡Buxton, Sir T. Fowell Warlies, Waltham Abbey, Essex
1854. ‡BYERLEY, ISAAC, F L S. Seacombe, Liverpool
Byng, William Bateman 2 Bank-street, Ipswich
1852. ‡Byrne, Very Rev. James Ergenagh Rectory, Omagh.
1875. §Byrom, W. Ascroft, F G S. 27 King-street, Wigan

1858. §Cail, John. Stokesley, Yorkshire,
1863. ‡Cail, Richard Beaconsfield, Gateshead
1854. ‡Caine, Nathaniel. 38 Belvedere-road, Princes Park, Liverpool.
1858. *Caine, Rev. William, M A. Christ Church Rectory, Denton, near Manchester
1876. §Caird, Alexander M'Neel. Genoch, Wigtonshire.
1868. ‡Caird, Edward. Finnart, Dumbartonshire.
1876. §Caird, Edward B 8 Scotland-street, Glasgow.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1855. *Caird, James Tennant. Belleaire, Greenock.

Year of
Election.

1875. ‡Caldicott, Rev. J. W., D D The Grammar School, Bristol.

1808. ‡Caley, A. J Norwich

1868. ‡Caley, W Norwich

1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College

1853. ‡Calver, Captain E. K , R N , F R S The Grange, Redhill, Surrey

1876 §Cameron, Charles, M D , LL.D , M P. 1 Huntly-gardens, Glasgow.

1857. ‡Cameron, Charles A., M D 15 Pembroke-road, Dublin.

1870 ‡Cameron, John, M D 17 Rodney-street, Liverpool

1857. *Campbell, Dugald, F C S 7 Quality-court, Chancery-lane, London, W C.

1874 *CAMPBELL, Sir GEORGE, K C S I , M P , D C L , F R G S. 13 Cornwall-gardens, South Kensington, London, S.W , and Edenwood, Cupar, Fife.

Campbell, Sir Hugh P. H , Bart 10 Hill-street, Berkeley-square, London, W., and Marchmont House, near Dunse, Berwickshire.

*Campbell, Sir James. 129 Bath-street, Glasgow.

1876 §Campbell, James A. 3 Claremont-terrace, Glasgow

Campbell, John Archibald, M D , F R S E Albyn-place, Edinburgh.

1872. ‡CAMPBELL, Rev J R , D D. 5 Eldon-place, Manningham-lane, Bradford, Yorkshire

1859 ‡Campbell, William Dunmore, Argyllshire

1871. ‡Campbell, William Hunter, LL D Georgetown, Demerara, British Guiana (Messrs. Ridgway & Sons, 2 Waterloo-place, London, S W)

CAMPBELL-JOHNSTON, ALEXANDER ROBERT, F R S 84 St George's-square, London, S W.

1876. §Campion, Frank, F G S , F.R G S. The Mount, Duffield-road, Derby.

1862. *CAMPION, Rev Dr WILLIAM M. Queen's College, Cambridge.

1868. *Cann, William 9 Southernhay, Exeter.

1873. *Carbutt, Edward Hamer, C.E. St Ann's, Burley, Leeds, Yorkshire.

*Carew, William Henry Pole Antony, Torpoint, Devonport.

1870. §Carlile, Thomas 5 St. James's-terrace, Glasgow

CARLISLE, The Right Rev. HARVEY GOODWIN, D D , Lord Bishop of Carlisle

1861. ‡Carlton, James Mosley-street, Manchester.

1867 ‡Carmichael, David (Engineer) Dundee.

1867. ‡Carmichael, George. 11 Dudhope-terrace, Dundee.

Carmichael, H.

Carmichael, John T. C. Messrs Todd & Co , Cork

1876. §Carmichael, Neil, M D 22 South Cumberland-street, Glasgow.

1871. ‡CARPENTER, CHARLES. Brunswick-square, Brighton.

1871. §Carpenter, Herbert P. 56 Regent's Park-road, London, N.W.

*CARPENTER, PHILIP PEARSALL, B A , Ph.D Montreal, Canada. (Care of Dr. W B. Carpenter, 56 Regent's Park-road, London, N.W.)

1854. ‡Carpenter, Rev. R Lant, B A. Bridport.

1845. ‡CARPENTER, WILLIAM B , C B , M.D , LL D., F.R S., F L.S., F.G.S , Registrar of the University of London. 56 Regent's Park-road, London, N.W.

1872. §CARPENTER, WILLIAM LANT, B A., B.Sc , F C.S. Winifred House, Pembroke-road, Clifton, Bristol

1842. *Carr, William, M.D., F.L.S., F.R C.S Lee Grove, Blackheath, S E.

1867. §CARRUTHERS, WILLIAM, F R.S., F.L.S., F.G.S. British Museum, London, W.C.

1861. *Carson, Rev. Joseph, D.D , M.R I.A. 18 Fitzwilliam-place, Dublin.

Year of
Election

1857 ‡CARTE, ALEXANDER, M D. Royal Dublin Society, Dublin
1868 ‡Carteighe, Michael, F C S 172 New Bond-street, London, W.
1866. ‡Carter, H H. The Park, Nottingham
1855 ‡Carter, Richard, C E , F G S Cockerham Hall, Barnsley, Yorkshire
1870. ‡Carter, Dr William 69 Elizabeth-street, Liverpool
*CARTMELL, Rev JAMES, D D , F G S , Master of Christ's College. Christ College Lodge, Cambridge
1870. §Cartwright, Joshua, A I C E ,'Borough Surveyor Bury, Lancashire.
1862 †Carulla, Facundo, F A S L Care of Messrs Daglish and Co , 8 Harrington-street, Liverpool.
1868 ‡Cary, Joseph Henry Newmarket-road, Norwich.
1866 ‡Casella, L P , F R A S South-grove, Highgate, London, N.
1871. ‡Cash, Joseph Bird Grove, Coventry
1873 *Cash, William 38 Elmfield-terrace, Saville Park, Halifax.
1842 **Cassels, Rev Andrew, M A*
Castle, Charles Clifton, Bristol
1874. §Caton, Richard, M D , Lecturer on Physiology at the Liverpool Medical School 18A Abercromby-square, Liverpool
1853. ‡Cator, John B , Commander R N 1 Adelaide-street, Hull.
1859. ‡Catto, Robert 44 King-street, Aberdeen
1873. *Cavendish, Lord Frederick, M P 21 Carlton House-terrace, London, S W
1849. ‡Cawley, Charles Edward The Heath, Kersall, Manchester
1860. §CAYLEY, ARTHUR, LL D , F R S , V P R A S , Sadleirian Professor of Mathematics in the University of Cambridge Garden House, Cambridge
Cayley, Digby Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire
1871 *Cecil, Lord Sackville Hayes Common, Beckenham, Kent.
1870 ‡Chadburn, C H Lord-street, Liverpool
1858. *Chadwick, Charles, M D Lynncourt, Broadwater Down, Tunbridge Wells
1860. ‡CHADWICK, DAVID, M P The Poplars, Herne Hill, London, S.E.
1842. CHADWICK, EDWIN, C.B Richmond, Surrey.
1842. Chadwick, Elias, M A. Pudleston Court, near Leominster.
1859. ‡Chadwick, Robert. Highbank, Manchester
1861. ‡Chadwick, Thomas Wilmslow Grange, Cheshire
*CHALLIS, Rev JAMES, M A , F R S , F R A S , Plumian Professor of Astronomy in the University of Cambridge. 2 Trumpington-street, Cambridge.
1859 ‡Chalmers, John Inglis. Aldbar, Aberdeen
1865. ‡CHAMBERLAIN, J. H. Christ Church-buildings, Birmingham.
1868. ‡Chamberlin, Robert. Catton, Norwich
1842. Chambers, George. High Green, Sheffield.
Chambers, John.
1868. ‡Chambers, W. O. Lowestoft, Suffolk.
*Champney, Henry Nelson. 4 New-street, York.
1865. ‡Chance, A. M. Edgbaston, Birmingham
1865. *Chance, James T. Four Oaks Park, Sutton Coldfield, Birmingham.
1865. §Chance, Robert Lucas Chad Hill, Edgbaston, Birmingham.
1861. *Chapman, Edward, M.A , F.L S , F C S Frewen Hall, Oxford.
1861. *Chapman, John, M.P. Hill End, Mottram, Manchester.
1866. ‡Chapman, William The Park, Nottingham
1871. §Chappell, William, F S.A. Strafford Lodge, Oatlands Park, Weybridge Station.
1874. ‡Charles, John James, M A., M.D 11 Fisherwick-place, Belfast.
1871. ‡Charles, T. C., M.D. Queen's College, Belfast.

Year of
Election

1836 CHARLESWORTH, EDWARD, F.G.S. 113A Strand, London, W.C.
1871 ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1863 ‡Charlton, Edward, M.D. 7 Eldon-square, Newcastle-on-Tyne.
1866 ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A., F.R.G.S. 8 Gray's-Inn-square, London, W.C.
Chatto, W. J. P. Union Club, Trafalgar-square, London, S.W.
1867 *Chatwood, Samuel. 5 Wentworth-place, Bolton.
1864 ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, W.
1874 *Chermside, Lieutenant H. C., R.E. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, London, S.W.
1872 §CHICHESTER, The Right Hon. the Earl of. Stanmer House, Lewes.
CHICHESTER, The Right Rev. RICHARD DURNFORD, Lord Bishop of Chichester.
1865 *Child, Gilbert W., M.A., M.D., F.L.S. Lee Place, Charlbury, Oxon.
1842 *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.
1863 ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.
1859 ‡Christie, John, M.D. 46 School-hill, Aberdeen.
1861 ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
CHRISTISON, Sir ROBERT, Bart., M.D., D.C.L., F.R.S.E., Professor of Dietetics, Materia Medica, and Pharmacy in the University of Edinburgh. Edinburgh.
1875 *Christopher, George, F.C.S. (ASSISTANT GENERAL TREASURER.) University College, London, W.C.
1876 *Chrystal, G. Corpus Christi College, Cambridge.
1870 §CHURCH, A. H., F.C.S. Professor of Chemistry in the Royal Agricultural College, Cirencester.
1866 ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.
1857 ‡*Churchill, F., M.D. 15 Stephen's-green, Dublin.*
1868 ‡Clabburn, W. H. Thorpe, Norwich.
1863 ‡Clapham, A. 3 Oxford-street, Newcastle-on-Tyne.
1863 ‡Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.
1855 §CLAPHAM, ROBERT CALVERT. Garsdon House, Garsdon, Newcastle-on-Tyne.
1869 §Clapp, Frederick. 44 Magdalen-street, Exeter.
1857 ‡Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square, Dublin.
Clark, Courtney K.
1859 ‡Clark, David. Coupar Angus, Fifeshire.
1876 §Clark, David R. Glasgow.
Clark, G. T. Bombay, and Athenæum Club, London, S.W.
1876 §Clark, George W. Glasgow.
1846 **Clark, Henry, M.D. 2 Arundel-gardens, Kensington, London, W.*
1876 §Clark, Dr. John. 138 Bath-street, Glasgow.
1861 ‡Clark, Latimer. 5 Westminster-chambers, Victoria-street, London, S.W.
1855 ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1865 ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
1875 §Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
Clarke, George. Mosley-street, Manchester.
1872 *CLARKE, HYDE. 32 St. George's-square, Pimlico, London, S.W.
1875 ‡CLARKE, JOHN HENRY. 4 Worcester-terrace, Clifton, Bristol.
1861 *Clarke, John Hope. Lark Hill House, Edgeley, Stockport.
1842 *Clarke, Joseph.*
1851. ‡CLARKE, JOSHUA, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.

Year of Election

1861 ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1856 *Clay, Colonel William. The Slopes, Wallasea, Cheshire.
1866 ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
187[illegible] ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1850 ‡CLEGHORN, HUGH, M.D., F.L.S., late Conservator of Forests, Madras. Stravithie, St. Andrews, Scotland.
1850 ‡Cleghorn, John. Wick.
1861 §CLELAND, JOHN, M.D., F.R.S., *Professor of Anatomy and Physiology in Queen's College, Galway.* Vicarscroft, Galway.
1857 ‡Clements, Henry. Dromin, Listowel, Ireland.
‡Clerk, Rev. D. M. Deverill, Warminster, Wiltshire.
1852 ‡Clibborn, Edward. Royal Irish Academy, Dublin.
1873 §Cliff, John. Halton, Runcorn.
1869 §CLIFFORD, WILLIAM KINGDON, M.A., F.R.S., Professor of Applied Mathematics and Mechanics in University College, London. 26 Colville-road, Bayswater, London, W.
1861 *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1854 ‡Close, The Very Rev. Francis, M.A. Carlisle.
1866 §CLOSE, THOMAS, F.S.A. St. James's-street, Nottingham.
1873 ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1859 ‡Clouston, Rev. Charles. Sandwick, Orkney.
1861 *Clouston, Peter. 1 Park-terrace, Glasgow.
1863 *Clutterbuck, Thomas. Warkworth, Acklington.
1868 ‡Coaks, J. B. Thorpe, Norwich.
1855 *Coats, Sir Peter. Woodside, Paisley.
1855 *Coats, Thomas. Ferguslie House, Paisley.
Cobb, Edward. 20 Park-street, Bath.
1851 *COBBOLD, JOHN CHEVALLIER. Holywells, Ipswich; and Athenæum Club, London, S.W.
1864 ‡COBBOLD, T. SPENCER, M.D., F.R.S., F.L.S., Lecturer on Zoology and Comparative Anatomy at the Middlesex Hospital. 42 Harley-street, London, W.
1864 *Cochrane, James Henry. 120 Lower Baggot-street, Dublin.
1854 ‡*Cockey, William.*
1861 *Coe, Rev. Charles C., F.R.G.S. Highfield, Manchester-road, Bolton.
1865 ‡Coghill, H. Newcastle-under-Lyme.
1876 §Colbourn, E. Rushton. 5 Marchmont-terrace, Hillhead, Glasgow.
1853 ‡Colchester, William, F.G.S. Grundesburgh Hall, Ipswich.
1868 ‡Colchester, W. P. Bassingbourn, Royston.
1859 *Cole, Henry Warwick, Q.C. 23 High-street, Warwick.
1876 §Colebrooke, Sir T. E., Bart., M.P., F.R.G.S. 37 South-street, Park-lane, London, W.; and Abington House, Abington, N.B.
1860 ‡Coleman, J. J., F.C.S. 69 St. George's-place, Glasgow.
1854 *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1857 ‡Colles, William, M.D. 21 Stephen's-green, Dublin.
1861 **Collie, Alexander. 12 Kensington Palace-gardens, London, W.*
1869 ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1854 ‡COLLINGWOOD, CUTHBERT, M.A., M.B., F.L.S. 4 Gove-terrace, Belvedere-road, Upper Norwood, Surrey, S.E.
1861 *Collingwood, J. Frederick, F.G.S. Anthropological Institute, 4 St. Martin's-place, London, W.C.
1865 *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876 §Collins, J. H., F.G.S. Truro, Cornwall.

Year of
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1876 §Collins, William. 3 Park-terrace East, Glasgow.
Collis, Stephen Edward. Listowel, Ireland.
1868 *COLMAN, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1870 §Coltart, Robert. The Hollies, Aigburth-road, Liverpool.
Colthurst, John. Clifton, Bristol.
1874 ‡Combe, James. Ormiston House, Belfast.
*COMPTON, The Ven. Lord ALWYNE. Castle Ashby, Northamptonshire; and 145 Piccadilly, London, W.
1846 *Compton, Lord William. 145 Piccadilly, London, W.
1852 ‡Connal, Michael. 16 Lynedoch-terrace, Glasgow.
1871 *Connor, Charles C. Hope House, College Park East, Belfast.
1864 *Conwell, Eugene Alfred, M.R.I.A. The Model Schools, Cork.
1876 §Cook, James. 162 North-street, Glasgow.
1870 §Cooke, Conrad W. 57 Tudor-road, Clapham Rise, London, S.W.
1863 ‡COOKE, EDWARD WILLIAM, R.A., F.R.S., F.R.G.S., F.L.S., F.G.S. Glen Andred, Groombridge, Sussex; and Athenæum Club, Pall Mall, London, S.W.
1868 ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
Cooke, James R., M.A. 73 Blessington-street, Dublin.
Cooke, J. B. Cavendish-road, Birkenhead.
1868 ‡COOKE, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
Cooke, Rev. T. L., M.A. Magdalen College, Oxford.
Cooke, Sir William Fothergill. Telegraph Office, Lothbury, London, E.C.
1859 *Cooke, William Henry, M.A., Q.C., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
1865 †Cooksey, Joseph. West Bromwich, Birmingham.
1863 ‡Cookson, N. C. Benwell Tower, Newcastle-on-Tyne.
1869 §Cooling, Edwin, F.R.G.S. Mile Ash, Derby.
1850 ‡COOPER, Sir HENRY, M.D. 7 Charlotte-street, Hull.
Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1875 ‡Cooper, T. T., F.R.G.S. Care of Messrs. King & Co., Cornhill, London, E.C.
1868 †Cooper, W. J. The Old Palace, Richmond, Surrey.
1846 ‡Cooper, William White, F.R.C.S. 19 Berkeley-square, London, W.
1871 ‡Copeland, Ralph, Ph.D. Parsonstown, Ireland.
1868 ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1863 ‡Coppin, John. North Shields.
1842 Corbett, Edward. Ravenoak, Cheadle-hulme, Cheshire.
1855 ‡Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology, Queen's College, Cork.
1870 *CORFIELD, W. H., M.A., M.B., F.G.S., Professor of Hygiène and Public Health in University College. 10 Bolton-row, Mayfair, London, W.
Cormack, John Rose, M.D., F.R.S.E.
Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
Cottam, George. 2 Winsley-street, London, W.
1857 ‡Cottam, Samuel. Brazennose-street, Manchester.
1855 ‡Cotterill, Rev. Henry, Bishop of Edinburgh. Edinburgh.
1874 *Cotterill, J. H., M.A., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864 §COTTON, General FREDERICK C., R.E., C.S.I. 13 Longridge-road, London, S.W.
1869 ‡COTTON, WILLIAM. Pennsylvania, Exeter.

Year of Election

*Cotton, Rev William Charles, M A Vicarage, Frodsham, Cheshire
1876 §Couper, James City Glass Works, Glasgow
1876 §Couper, James, jun City Glass Works, Glasgow
1865 ‡Courtauld, Samuel, F R A S 76 Lancaster-gate, London, W, and Gosfield Hall Essex
1874 §Courtauld, John M Bocking Bridge, Braintree Essex
1834 ‡Cowan, Charles 38 West Register-street, Edinburgh
1876 §Cowan, J B 159 Bath-street, Glasgow
Cowan, John Valleyfield, Pennycuick Edinburgh
1863 ‡Cowan, John A Blaydon Burn Durham
1863 ‡Cowan, Joseph jun Blaydon, Durham
1872 *Cowan, Thomas William Hawthorn House, Horsham
1873 *Cowans John Cranford, Middlesex
Cowie, The Very Rev Benjamin Morgan, M A, B D, Dean of Manchester The Deanery, Manchester
1871 ‡Cowper, C E 3 Great George-street, Westminster, S W
1860 ‡Cowper, Edward Alfred, M I C E 6 Great George-street, Westminster, S W
1867 *Cox, Edward 18 Windsor street, Dundee
1867 *Cox, George Addison Beechwood, Dundee
1867 ‡Cox, James Clement Park Lochee, Dundee
1870 *Cox, James 8 Falkner square Liverpool
Cox, Robert 25 Rutland-street, Edinburgh
1867 *Cox, Thomas Hunter Duncarse, Dundee
1867 ‡Cox, William Foggley, Lochee, by Dundee
1866 *Cox, William H 50 Newhall-street, Birmingham
1871 ‡Cox, William J 2 Vanburgh place, Leith
Craig, J T Gibson, F R S E 24 York place, Edinburgh
1859 ‡*Craig, S The Wallands, Lewes, Sussex*
1876 §Cramb, John Larch Villa, Helensburgh N B
1857 ‡Crampton, Rev Josiah The Rectory, Florence-court, Co Fermanagh, Ireland
1858 ‡Cranage, Edward, Ph D The Old Hall, Wellington, Shropshire
1876 §Crawford, Chalmond, M P Ridemon, Crossear
1871 *Crawford, William Caldwell Eagle Foundry, Port Dundas, Glasgow.
1871 ‡Crawshaw, Edward Burnley, Lancashire
1870 *Crawshay, Mrs Robert Cyfarthfa Castle, Merthyr Tydvil
1876 *Crewdson, Rev George St George's Vicarage, Kendal
Creyke, The Venerable Archdeacon Bolton Percy Rectory, Tadcaster
1865 ‡*Crocker, Edwin, F C S 76 Hungerford road, Holloway, London, N*
1858 ‡Crofts, John Hillary-place, Leeds
1859 ‡Croll, A A. 10 Coleman-street, London, E C
1857 ‡Crolly, Rev George Maynooth College, Ireland
1855. ‡*Crompton, Charles, M A*
*CROMPTON, Rev JOSEPH, M A Bracondale, Norwich.
1866 ‡Cronin, William 4 Brunel-terrace, Nottingham
1870 ‡Crookes, Joseph Marlborough House, Brook Green, Hammersmith, London, W
1865 §CROOKES, WILLIAM, F R S, F C S 20 Mornington-road, Regent's Park, London, N W
1855 ‡Cropper, Rev John Wareham, Dorsetshire
1870 ‡Crosfield, C J 16 Alexandra-drive, Prince's Park, Liverpool
1870. *Crosfield, William, jun 16 Alexandra-drive, Prince's Park, Liverpool
1870 ‡Crosfield, William, sen Annesley, Aigburth, Liverpool
1861 ‡Cross, Rev John Edward, M A Appleby Vicarage, near Brigg
1868 ‡Crosse, Thomas William St Giles's-street, Norwich

Year of Election

1867 §Crosskey, Rev H W, F G S 28 George-road, Edgbaston, Birmingham
1853 ‡Crosskill William, C E Beverley, Yorkshire
1870 *Crossley Edward, F R A S Bermerside, Halifax
1871 ‡Crossley, Herbert Broomfield, Halifax
1866 *Crossley, Louis J, F M S Moorside Observatory, near Halifax.
1861 §Crowley, Henry Smedley New Hall, Cheetham, Manchester
1863 ‡Cruddas, George Elswick Engine Works Newcastle-on-Tyne.
1860 ‡Cruickshank, John City of Glasgow Bank, Aberdeen
1859 ‡Cruickshank Provost Macduff Aberdeen
1873 §Crust, Walter Hall street, Spalding
Culley, Robert Bank of Ireland, Dublin
1859 ‡Cumming Sir A P Gordon, Bart Altyre
1874 ‡Cumming Professor 33 Wellington-place, Belfast
1876 §Cunlif, Richard S Carlton House, Stirling
1861 *Cunliffe, Edward Thomas The Elms, Handforth, Manchester.
1861 *Cunliffe, Peter Gibson The Elms, Handforth, Manchester
1852 ‡Cunningham John Macedon, near Belfast
1869 ‡Cunningham, Professor Robert O, M D, F L S Queen s College, Belfast
1855 ‡Cunningham, William A Manchester and Liverpool District Bank, Manchester
1850 ‡Cunningham, Rev William Bruce Prestonpans, Scotland
1866 ‡Cunnington, John 68 Oakley square, Bedford New Town, London, N W
1867 *Cursetjee Manockjee, F R S A, Judge of Bombay Villa Byculla, Bombay
1857 ‡Curtis, Professor Arthur Hill, LL D Queen s College, Galway
1866 ‡*Cussns Rev F I*
1834 *Cuthbert, John Richmond 40 Chapel-street, Liverpool

1863 ‡Daglish, John Hetton, Durham
1851 ‡Daglish, Robert, C E Orrell Cottage, near Wigan
1863 ‡Dale, J B South Shields
1853 ‡Dale, Rev P Steele, M A Hollingfare, Warrington
1865 ‡Dale, Rev R W 12 Calthorpe street, Birmingham
1867 ‡Dalgleish, W Dundee
1870 ‡*Dallinger, Rev W H*
Dalmahoy, James, F R S E 9 Forres-street, Edinburgh
1859 ‡Dalrymple, Charles Elphinstone West Hall, Aberdeenshire
1859 ‡Dalrymple, Colonel Troup Scotland
Dalton, Edward H D, F S A Dunkirk House, Nailsworth
*Dalton, Rev J E, B D Seagrave, Loughborough
Dalziel, John, M D Holm of Drumlanrig, Thornhill, Dumfriesshire
1862 ‡Danby, T W Downing College, Cambridge
1850 ‡Dancer J B F R A S Old Manor House, Ardwick, Manchester
1873 ‡*Danchill, F H Vale Hall, Horwich, Bolton, Lancashire*
1876 §Dansken, John 4 Eldon-terrace, Partickhill, Glasgow
1849 **Danson, Joseph, F C S*
1861 *Darbishire, Robert Dukinfield, B A, F G S 26 George-street, Manchester
1876 §Darling, G Erskine 247 West George-street, Glasgow
Darwin, Charles R, M A, F R S, F L S, F G S, Hon F.R S E, and M R I A Down, near Bromley, Kent.
1848 ‡DaSilva, Johnson. Burntwood, Wandsworth Common, London, S W.

Year of
Election.

1872 §Davenport, John T 64 Marine Parade, Brighton
Davey, Richard F G S Redruth Cornwall
1870 ‡Davidson, Alexander M D 8 Peel-street Toxteth Park, Liverpool
1859 ‡Davidson, Charles Grove House Auchmull Aberdeen
1871 §Davidson James Newbattle Dalkeith N B
1859 ‡Davidson, Patrick Inchmarlo near Aberdeen
1872 ‡DAVIDSON, THOMAS, F R S, F G S 3 Leopold road Brighton
1868 ‡*Davie Rev W C*
1875 ‡Davies David 2 Queen's square, Bristol
1870 ‡Davies, Edward, F C S Royal Institution, Liverpool
1863 ‡*Davies, Griffith 17 Cloudesley street Islington, London N*
Davies, John Birt, M D The Laurels, Edgbaston Birmingham
1842 Davies Colley, Dr Thomas 40 Whitefriars, Chester
1873 *Davis, Alfred Sun Foundry, Leeds
1870 *Davis, A S Roundhay Villa Leckhampton-road Cheltenham
1864 ‡DAVIS, CHARLES E F S A 55 Pulteney street, Bath
Davis, Rev David, B A Lancaster
1873 *Davis James W Albert House, Greetland near Halifax
1856 *DAVIS, SIR JOHN FRANCIS Bart K C B, F R S, F R G S Hollywood Westbury by Bristol
1859 ‡DAVIS, J BARNARD, M D, F R S, F S A Shelton, Hanley, Staffordshire
1859 *Davis, Richard, F L S 9 St Helen's place, London, E C
1873 ‡Davis, William Samuel 1 Cambridge villas, Derby
1864 *Davison Richard Beverley road Great Driffield, Yorkshire
1857 ‡Davy, Edmund W, M D Kimmage Lodge, Roundtown, near Dublin
1869 ‡Daw, John Mount Radford, Exeter
1869 ‡Daw R M Bedford circus Exeter
1854 *Dawbarn, William Elmswood Aigburth, Liverpool
Dawes John Samuel, F G S Lappel Lodge, Quinton, near Birmingham
1860 *Dawes, John T, jun Perry Hill House, Quinton, near Birmingham
1864 ‡DAWKINS, W BOYD, M A, F R S, F G S, F S A Birchview, Norman road, Rusholme, Manchester
1865 ‡*Dawson, George, M A Shenstone Lichfield*
Dawson, John Barley House Exeter
1855 ‡DAWSON, JOHN W, M A, LL D, F R S, F G S, Principal of M'Gill College, Montreal, Canada
1859 *Dawson, Captain William G Plumstead Common road, Kent, S E
1871 ‡DAY, ST JOHN VINCENT, C E, F R S E 166 Buchanan street, Glasgow
1870 §DEACON, G F, M I C E Rock Ferry, Liverpool
1861 ‡Deacon, Henry Appleton House, near Warrington
1870 ‡*Deacon, Henry Wade*
1859 ‡Dean, David Banchory, Aberdeen
1861 ‡Dean, Henry Colne, Lancashire
1870 *Deane, Rev George, D Sc, B A, F G S Moseley, Birmingham
1866 ‡DEBUS, HEINRICH, Ph D, F R S, F C S Lecturer on Chemistry at Guy's Hospital, London, S E
1854 *DE LA RUE, WARREN, D C L, Ph D, F R S, F C S, F R A S 73 Portland-place, London, W
1870 ‡De Meschin, Thomas, M A, LL D 3 Middle Temple lane, Temple, London, E C
Denchar, John Morningside, Edinburgh

Year of Election

1875 §Denny, William. Leven Ship-yard, Dumbarton.

Dent, William Yerbury. Royal Arsenal, Woolwich.

1870 *Denton, J. Bailey. 22 Whitehall-place, London, S.W.

1871 §DE RANCE, CHARLES E., F.G.S. 28 Jermyn-street, London, S.W.

1850 *DERBY, The Right Hon. the Earl of, LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London, S.W.; and Knowsley, near Liverpool.

1874 *Derham, Walter, B.A., F.G.S. Henleaze Park, Westbury-on-Trym, Bristol.

De Saumarez, Rev. Havilland, M.A. St. Peter's Rectory, Northampton.

1870 ‡Desmond, Dr. 44 Irvine-street, Edge Hill, Liverpool.

1868 ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.

DE TABLEY, GEORGE, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.

1860 ‡DEVON, The Right Hon. the Earl of, D.C.L. Powderham Castle, near Exeter.

*DEVONSHIRE, His Grace the Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.

1868 ‡DEWAR, JAMES, M.A., F.R.S.E., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural Philosophy in the University of Cambridge. Cambridge.

1872 ‡Dewick, Rev. E. S. The College, Eastbourne, Sussex.

1873 *Dew-Smith, A. G. 7A Eaton-square, London, S.W.

1858 ‡Dibb, Thomas Townend. Little Woodhouse, Leeds.

1852 ‡DICKIE, GEORGE, M.A., M.D., F.L.S., Professor of Botany in the University of Aberdeen.

1864 *Dickinson, F. H., F.G.S. Kingweston, Somerton, Taunton; and 121 St. George's-square, London, S.W.

1863 ‡Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.

1861 *Dickinson, William Leeson. Halam, near Southwell, Nottinghamshire.

1867 ‡DICKSON, ALEXANDER, M.D., Professor of Botany in the University of Glasgow. 11 Royal-circus, Edinburgh.

1876 §Dickson, Gavin Irving. 37 West George-street, Glasgow.

1862 *DILKE, Sir CHARLES WENTWORTH, Bart., M.P., F.R.G.S. 76 Sloane-street, London, S.W.

1848 ‡DILLWYN, LEWIS LLEWELYN, M.P., F.L.S., F.G.S. Parkwern, near Swansea.

1872 §Dines, George. Woodside, Hersham, Walton-on-Thames.

1869 ‡Dingle, Edward. 19 King-street, Tavistock.

1859 *Dingle, Rev. J. Lanchester Vicarage, Durham.

1876 §Ditchfield, Arthur. 12 Taviton-street, Gordon-square, London, W.C.

1868 ‡Dittmar, W. Andersonian University, Glasgow.

1874 *Dixon, A. L. Dunowen, Cliftonville, Belfast.

1859 ‡Dixon, Edward, M.I.C.E. Wilton House, Southampton.

1865 ‡*Dixon, I.*

1861 ‡DIXON, W. HEPWORTH, F.S.A., F.R.G.S. 6 St. James's-terrace, Regent's-park, London, N.W.

*Dobbin, Leonard, M.R.I.A. 27 Gardiner's-place, Dublin.

1851 ‡Dobbin, Orlando T., LL.D., M.R.I.A. Ballivor, Kells, Co. Meath.

1860 *Dobbs, Archibald Edward, M.A. 34 Westbourne Park, London, W.

1864 Dobson, William. Oakwood, Bathwick Hill, Bath.

Dockray, Benjamin.

1875 *Docwra, George, jun. Grosvenor-road, Handsworth, Birmingham.

Year of Election

1870 *Dodd, John. 6 Thomas-street, Liverpool.
1874 ‡*Dodd, W. H., M.A. Mountjoy-street, Dublin.*
1876 ‡Dodds, J. M. 15 Sandyford-place, Glasgow.
1857. ‡*Dodds, Thomas W., C.E. Rotherham.*
*Dodsworth, Benjamin. Burton House, Scarborough.
*Dodsworth, George. The Mount, York.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1851. ‡Domvile, William C., F.Z.S. Thorn Hill, Bray, Dublin.
1867 ‡Don, John. The Lodge, Broughty Ferry, by Dundee.
1867 ‡Don, William G. St. Margaret's, Broughty Ferry, by Dundee.
1873 ‡Donham, Thomas. Huddersfield.
1869 ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1871 ‡*Donkin, Arthur Scott, M.D. Sunderland.*
1874 ‡Donnell, Professor, M.A. 28 Upper Sackville-street, Dublin.
1861 ‡Donnelly, Captain, R.E. South Kensington Museum, London, W.
1857. *DONNELLY, WILLIAM, C.B., Registrar General for Ireland. Charlemont House, Dublin.
1857 ‡Donovan, M., M.R.I.A. Clare-street, Dublin.
1867 ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871 ‡Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.
1863 **Doughty, C. Montagu.*
1876 *Douglas, Rev. G. C. M. 10 Fitzroy-place, Glasgow.
1855 ‡DOVE, HECTOR. Rose Cottage, Trinity, near Edinburgh.
1870 ‡Dowie, J. M. Walstones, West Kirby, Liverpool.
1876 §Dowie, Mrs. Muir. Walstones, West Kirby, Liverpool.
Downall, Rev. John. Okehampton, Devon.
1857 ‡DOWNING, S., LL.D., Professor of Civil Engineering in the University of Dublin. Dublin.
1872 *Dowson, Edward, M.D. 117 Park-street, London, W.
1865 *Dowson, E. Theodore. Geldeston, near Beccles, Suffolk.
1868 §DRESSER, HENRY E., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.
1873 §Drew, Frederick, LL.D., F.G.S. Claremont-road, Surbiton.
1860 §Drew, Joseph, LL.D., F.R.A.S., F.G.S. Weymouth.
1865 ‡Drew, Robert A. 6 Stanley-place, Duke-street, Broughton, Manchester.
1872 *Druce, Frederick. 27 Oriental-place, Brighton.
1874 ‡Druitt, Charles. Hampden-terrace, Rugby-road, Belfast.
1859 ‡*Drummond, Robert. 17 Stratton Street, London, W.*
1866 *Dry, Thomas. 23 Gloucester-road, Regent's Park, London, N.W.
1863 ‡*Dryden, James. South Benwell, Northumberland.*
1870 §Drysdale, J. J., M.D. 36A Rodney-street, Liverpool.
1856 *DUCIE, The Right Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1870 ‡Duckworth, Henry, F.L.S., F.G.S. 5 Cook-street, Liverpool.
1867 *DUFF, MOUNTSTUART ELPHINSTONE GRANT, LL.B., M.P. 4 Queen's Gate-gardens, South Kensington, London, W.; and Eden, near Banff, Scotland.
1852. ‡Dufferin and Claneboye, The Right Hon. the Earl of, K.P., K.C.B., F.R.S. Government House, Ottawa, Canada.
1875 §Duffin, C. L'Estrange, C.E. Rathkeale, Co. Limerick.
1859 *Duncan, Alexander. 7 Prince's-gate, London, S.W.
1859 ‡Duncan, Charles. 52 Union-place, Aberdeen.
1866. *Duncan, James. 71 Cromwell-road, South Kensington, London, W.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1871. ‡Duncan, James Matthew, M.D. 30 Charlotte-square, Edinburgh.

Year of
Election

1867 ‡DUNCAN PETER MARTIN M B F R S F G S Professor of Geology in Kings College London 99 Abbey road St Johns Wood London N W
Dunlop Alexander Clober Milngavie, near Glasgow
1853 *Dunlop William Henry Annanhill Kilmarnock Ayrshire
1865 ‡Dunn David Annet House Skelmorlie by Greenock N B
18 0 *Dunn James 34 Robertson street Glasgow
1869 §DUNN ROBERT F R C S 31 Norfolk street Strand London W C
1876 §Dunnachie James West Regent street Glasgow
Dunnington Jefferson Rev Joseph M A F C P S Thicket Hall York
1850 ‡Duns Rev John D D F R S E New College Edinburgh
1866 ‡Duprey J l r Woodberry Down Stoke Newington London N
1869 ‡D'Urban W S M I I S 4 Queen terrace Mount Radford Exeter
1860 ‡DURHAM ARTHUR EDWARD F R C S F L S Demonstrator of Anatomy Guys Hospital 8 Brook street Grosvenor square London W
Dyke Robert Kilmorie Torquay Devon
1869 §Dymond Edward E Oaklands Aspley Guise Woburn

1868 ‡Eade Peter M D Upper St Giles street Norwich
18 1 ‡Eadson Richard 13 Hyde road Manchester
1 4 ‡*Ea l A*
*EARNSHAW Rev SAMUEL M A 14 Broomfield Sheffield
1874 §Eason Charles 30 Kenilworth square Rathgar Dublin
1871 *EASTON EDWARD 7 Delahay street Westminster S W
1863 §Easton James Nest House near Ca sl ad Durham
18 0 §Easton John C F Dune House Abercromby street Helensburgh N B
Eaton Rev George M A The P l Northwich
1870 §Eaton Richard Basford Nottingham
Ebden Rev James Collett M A F R A S Great Stukeley Vicarage Huntingdonshire
1867 ‡*Eckersley James*
1861 ‡Ecroyd William Farrer Spring Cottage near Burnley
1858 *Eddison Francis Martinstown Dorchester
1870 *Eddison Dr John Edwin 29 Park square Leeds
*Eddy James Ray F C S Carleton Grange Skipton
Eden Thomas Talbot road Oxton
*EDGEWORTH MICHAEL P F L S F R A S Mastrim House Anerley London S E
1855 ‡Edmiston Robert Elmbank crescent Glasgow
1859 ‡Edmond James Cardens Haugh Aberdeen
1870 *Edmonds F B 8 York place Northam Southampton
1867 *Edward Allan Farington Hall Dundee
1867 ‡Edward Charles Chambers 8 Bank street Dundee
1867 ‡Edward James Balruddery Dundee
Edwards John
1855 *EDWARDS Professor J BAKER Ph D D C L Montreal Canada
1867 ‡Edwards William 70 Princes street Dundee
*EGERTON Sir PHILIP DE MALPAS GREY Bart M P F R S F G S Oulton Park Tarporley Cheshire
1859 *Eisdale David A M A 38 Dublin street Edinburgh
1873 ‡Elcock Charles 39 Lyme street Shakspere street Ardwick Manchester
1876 §Elder Mrs 6 Claremont terrace Glasgow

Year of Election

1868 ‡Elger, Thomas Gwyn Empy, F R A S St Mary, Bedford
Ellacombe, Rev H T, F S A Clyst, St George, Topsham, Devon
1863 ‡Ellenberger, J L Worksop
1855 §Elliot, Robert, F B S L Wolfelee, Hawick, N B
1861 *Elliot, Sir Walter, K C S I, F L S Wolfelee, Hawick, N B
1864 ‡Elliott, E B Washington, United States
1872 ‡Elliott, Rev E B 11 Sussex square, Kemp Town, Brighton
Elliott, John Fogg Elvet Hill, Durham
1864 *Ellis, Alexander John, B A, F R S, F S A 25 Argyll road, Kensington, London, W
1877 §Ellis, Arthur Devonshire School of Mines, Jermyn street, London, S W, and Thurnscoe Hall, Rotherham, Yorkshire
1875 *Ellis, H D Fair Park House, Exeter
1859 ‡Ellis, Henry S, F R A S Fair Park, Exeter
1864 *Ellis, Joseph Hampton Lodge, Brighton
1864 ‡Ellis, J Walter High House, Thornwaite, Ripley, Yorkshire
*Ellis, Rev Robert, A M The Institute, St Saviours Gate, York
1874 *Ellis, Sydney The Newarke, Leicester
1869 ‡Ellis, William Horton Pennsylvania, Exeter
Ellman, Rev E B Berwick Rectory, near Lewes, Sussex
1862 ‡Elphinstone, H W, M A, F L S Cadogan-place, London, S W
Eltoft, William
1863 ‡Embleton, Dennis, M D Northumberland street, Newcastle-on-Tyne
1863 ‡Emery, Rev W, B D Corpus Christi College, Cambridge
1858 ‡Empson, Christopher Bramhope Hall, Leeds
1866 ‡Enfield, Richard Low Pavement, Nottingham
1866 ‡Enfield, William Low Pavement, Nottingham
1871 ‡*Engelsen, I 11 Portland terrace, Regent's Park, London, N W*
1853 ‡English, Edgar Wilkins Yorkshire Banking Company, Lowgate, Hull
1869. ‡English, J T Stratton, Cornwall
Enniskillen, The Right Hon William Willoughby, Earl of, D C L, F R S, M R I A, F G S 65 Eaton place, London, S W, and Florence Court, Fermanagh, Ireland
1869 ‡Ensor, Thomas St Leonards, Exeter
1869 *Enys, John Davis 33 Cambridge terrace, Hyde Park, London, W
1844 ‡Erichsen, John Eric, F R S, F R C S Professor of Clinical Surgery in University College, London 6 Cavendish place, London, W
1864 *Eskrigge, R A, F G S 18 Hackins hey, Liverpool
1862 *Esson, William, M A, F R S, F C S, F R A S Merton College, and 1 Bradmore road, Oxford
Estcourt, Rev W J B Long Newton, Tetbury
1869 ‡Etheridge, Robert, F R S L & E, F G S, Palæontologist to the Geological Survey of Great Britain Museum of Practical Geology, Jermyn street, and 19 Halsey-street, Cadogan-place, London, S W
1870 *Evans, Arthur John, F S A Nash Mills, Hemel Hempstead
1865 *Evans, Rev Charles, M A The Rectory, Solihull, Birmingham
1872 *Evans, Frederick J, C E Clayponds, Brentford, Middlesex, W.
1870. §Evans, Captain Frederick J O, C B, R N, F R S, F R A S, F R G S, Hydrographer to the Admiralty 116 Victoria-street, Westminster, S W
1869 *Evans, H Saville W Wimbledon Park House, Wimbledon, S W
1861. *Evans, John, F R S, F S A, F G S 65 Old Bailey, London, E C, and Nash Mills, Hemel Hempstead.

Year of Election.

1876 §Evans, Mortimer, C.E., 97 West Regent-street, Glasgow.
1865 ‡EVANS, SEBASTIAN, M.A., LL.D. Highgate, near Birmingham.
1875 ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1866 ‡Evans, Thomas, F.G.S. Belper, near [illegible]
1865 *Evans, William Llewellin. Augustus-road, Edgbaston, Birmingham.
1871 §Eve, H. W. Wellington College, Wokingham, Berkshire.
1868 *EVERETT, J. D., D.C.L., F.R.S.E., Professor of Natural Philosophy in Queen's College, Belfast. Rushmere, Malone-road, Belfast.
1863 *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1874 ‡Ewart, William. Glenmachan, Belfast.
1874 ‡Ewart, W. Quartus. Glenmachan, Belfast.
1859 *Ewing, Archibald Orr, M.P. Ballikinrain Castle, Killearn, Stirlingshire.
1876 *Ewing, James Alfred. 22 India-street, Edinburgh.
1871 *Exley, John T., M.A. 1 Cotham-road, Bristol.
1846 *Eyre, George Edward, F.G.S., F.R.G.S. 59 Lowndes-square, London, S.W.; and Warrens, near Lyndhurst, Hants.
1866 ‡EYRE, Major-General Sir VINCENT, F.R.G.S. Athenæum Club, Pall Mall, London, S.W.
Eyton, Charles. Hendred House, Abingdon.
1849 ‡Eyton, T. C. Eyton, near Wellington, Salop.

1842 Fairbairn, Thomas. Manchester.
1865 ‡Fairley, Thomas, F.R.S.E. 8 Newton-grove, Leeds.
1870 ‡Fairlie, Robert, C.E. Woodlands, Clapham Common, London, S.W.
1864 ‡Falkner, F. H. Lyncombe, Bath.
1859 ‡Farquharson, Robert O. Houghton, Aberdeen.
1861 §FARR, WILLIAM, M.D., D.C.L., F.R.S., Superintendent of the Statistical Department, General Register Office, London. Southlands, Bickley, Kent.
1866 *FARRAR, Rev. FREDERICK WILLIAM, D.D., F.R.S., Canon of Westminster. St. Margaret's Rectory, Westminster, S.W.
1857 ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869 *Faulconer, R. S. Fairlawn, Clarence-road, Clapham Park, London, S.W.
1869 *Faulding, Joseph. The Grange, Greenhill Park, New Barnet, Herts.
1869 ‡Faulding, W. F. Didsbury College, Manchester.
1859 *FAWCETT, HENRY, M.A., M.P., Professor of Political Economy in the University of Cambridge. 51 The Lawn, South Lambeth-road, London, S.W.; and 8 Trumpington-street, Cambridge.
1863 ‡Fawcus, George. Alma-place, North Shields.
1873 *Fazakerley, Miss. The Castle, Denbigh.
1845 ‡Felkin, William, F.L.S. The Park, Nottingham.
Fell, John B. Spark's Bridge, Ulverston, Lancashire.
1864 §FELLOWS, FRANK P., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852 ‡Fenton, S. Greame. 9 College-square, and Keswick, near Belfast.
1876 *Fergus, Andrew, M.D. 3 Elmbank-crescent, Glasgow.
1876 §Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1859 ‡Ferguson, John. Cove, Nigg, Inverness.
1871 *Ferguson, John, M.A., Professor of Chemistry in the University of Glasgow.
1867 ‡Ferguson, Robert M., Ph.D., F.R.S.E. 8 Queen-street, Edinburgh.
1857 ‡Ferguson, Samuel. 20 North Great George-street, Dublin.
1854 ‡Ferguson, William, F.L.S., F.G.S. Kinmundy, near Mintlaw, Aberdeenshire.
1867 *Fergusson, H. B. 13 Airlie-place, Dundee.

Year of Election

1863 *FERNIE, JOHN Bonchurch, Isle of Wight
1862 ‡FERRERS, Rev N M, M A Caius College Cambridge
1873 ‡Ferrier, David, M A M D, F R S Professor of Forensic Medicine in King's College 16 Upper Berkeley-street London W
1875 ‡Fiddes, Walter Clapton Villa, Tyndall's Park, Clifton, Bristol
1868 ‡Field, Edward Norwich
1869 *FIELD, ROGERS, B A, C E 5 Cannon row, Westminster, S W
1876 §Fielden, James 2 Darnley street, Pollokshields near Glasgow
Fielding G H M D
1864 ‡Finch, Frederick George, B A, F G S 21 Crooms-hill, Greenwich, S E
Finch John Bridge Work Chepstow
Finch, John, jun Bridge Work, Chepstow
1863 ‡*Finney, Samuel*
1868 ‡Firth, G W W St Giles's street, Norwich
Firth, Thomas Northwick
1863 *Firth, William Burley Wood near Leeds
1851 *FISCHER WILLIAM L F M A, LL D F R S Professor of Mathematics in the University of St Andrews St Andrews, Scotland
1858 ‡Fishbourne, Captain E G, R N 6 Welamere-terrace, Paddington, London, W
1869 ‡FISHER, Rev OSMOND M A, F G S Harlston Rectory, near Cambridge
1873 §Fisher, William Maes Fron near Welshpool, Montgomeryshire
1875 *Fisher, W W, M A, F C S 2 Park crescent Oxford
1858 ‡Fishwick, Henry Carr-hill, Rochdale
1871 *Fison Frederick W, F C S Eastmoor, Ilkley, Yorkshire
1871 §FITCH, J G, M A 5 Lancaster-terrace, Regent's Park, London, N W
1868 ‡Fitch, Robert F G S F S A Norwich
1857 ‡Fitzgerald The Right Hon Lord Otho 13 Dominick street, Dublin
1857 ‡Fitzpatrick Thomas, M D 31 Lower Bagot street, Dublin
Fitzwilliam, Hon George Wentworth, F R G S 19 Grosvenor-square, London, S W, and Wentworth House, Rotherham
1865 ‡Fleetwood, D J 45 George street St. Paul's, Birmingham
Fleetwood, Sir Peter Hesketh, Bart Rossall Hall, Fleetwood, Lancashire
1850 ‡Fleming, Professor Alexander M D 121 Hagley-road Birmingham
Fleming, Christopher M D Merrion-square North, Dublin
1876 §Fleming, James Brown Beaconsfield, Kelvinside near Glasgow
Fleming, John G, M D 155 Bath-street, Glasgow
1876 §Fleming, Sandford Ottawa Canada
*FLEMING, WILLIAM, M D Rowton Grange, near Chester
1867 §FLETCHER, ALFRED E 21 Overton-street, Liverpool
1870 ‡Fletcher B Edgington Norwich
1853 ‡FLETCHER, ISAAC, M P, F R S, F R A S, F G S Tarn Bank, Workington
1869 ‡FLETCHER, LAVINGTON E, C E 41 Corporation-street, Manchester
Fletcher, T B E, M D 7 Waterloo-street, Birmingham
1862 ‡FLOWER, WILLIAM HENRY, F R S, F L S, F G S, F R C S, Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons Royal College of Surgeons, Lincoln's Inn-fields, London, W C
1867 ‡Foggie, William Woodville, Maryfield, Dundee
1854 *FORBES, DAVID, F R S, F G S, F C S 11 York-place, Portman-square, London, W
1873 *Forbes, Professor George, M A, F R S E Andersonian University, Glasgow

Year of
Election

1855 ‡Forbes Rev John Symington Manse Biggar, Scotland
Ford, H R Morecombe Lodge Yealand Conyers, Lancashire
1866 ‡Ford, William Hartsdown Villa, Kensington Park-gardens East, London W
1875 *FORDHAM H GEORGE, F G S Odsey near Royston, Herts
*Forrest William Hutton The Terrace Stirling
1867 ‡Forster Anthony Finlay House, St Leonard's on Sea
1858 *FORSTER The Right Hon WILLIAM EDWARD M P F R S 80 Eccleston square London S W , and Wharfeside, Burley in-Wharfedale Leeds
1871 ‡*Forsyth William J*
1854 *Fort, Richard Read Hall, Whalley Lancashire
1870 ‡Forwood William B Hopeton House, Seaforth Liverpool
1875 ‡Foster A Le Neve East Hill, Wandsworth Surrey, S W
1865 †Foster Balthazar W , M D 4 Old square Birmingham
1865 *FOSTER, CLEMENT LE NEVE, B A , D Sc , F G S Truro, Cornwall
1857 *FOSTER GEORGE CAREY B A F R S F C S Professor of Physics in University College London 12 Hilldrop road, London, N
*Foster, Rev John M A The Oaks Vicarage Loughborough
1845 ‡Foster John N Sandy Place Sandy Bedfordshire
1859 *FOSTER MICHAEL M A M D F R S F L S F C S Trinity College and Great Shelford near Cambridge
1859 §FOSTER PETER LE NEVE M A Society of Arts Adelphi, London, W C
1873 ‡Foster Peter Le Neve jun Society of Arts, Adelphi, London, W C
1863 ‡Foster Robert 30 Rye hill Newcastle upon Tyne
1859 *Foster S Lloyd Old Park Hall, Walsall Staffordshire
1873 *Foster, William Harrowins House Queensbury, Yorkshire
1842 *Fothergill Benjamin 10 The Grove, Boltons, West Brompton, London S W*
1870 ‡Foulger, Edward 55 Kirkdale road, Liverpool
1866 §Fowler George Basford Hall near Nottingham
1868 ‡Fowler, G G Gunton Hall Lowestoft, Suffolk
1856 ‡Fowler, Rev Hugh M A College gardens, Gloucester
1876 §Fowler, John 4 Gray street, Glasgow
1870 *Fowler Robert Nicholas M A F R G S 50 Cornhill, London, E C
1868 ‡Fox Colonel A H LANE, F R S , F G S , F S A Guildford, Surrey
1842 *Fox, Charles Trebah Falmouth
*Fox, Rev Edward M A The Vicarage Romford, Essex
1876 §Fox, G S Lane 9 Sussex-place London S W
*Fox, Joseph Hayland The Clove, Wellington, Somerset
1860 ‡Fox, Joseph John Church row Stoke Newington, London, N
Fox, ROBERT WERE, F R S Penjerrick, Falmouth
1866 *Francis G B Inglesby House, Stoke Newington green, London N
FRANCIS WILLIAM, Ph D F L S , F G S F R A S Red Lion-court, Fleet street, London, E C , and Manor House, Richmond, Surrey
1846 ‡FRANKLAND, EDWARD, D C L , Ph D , F R S , F C S , Professor of Chemistry in the Royal School of Mines 14 Lancaster-gate, London W
*Frankland Rev Marmaduke Charles Chowbent, near Manchester
1859 ‡Fraser, George B 3 Airlie-place, Dundee
Fraser, James 25 Westland-row, Dublin
Fraser, James William 8A Kensington Palace gardens, London, W
1865 *FRASER, JOHN, M A , M D Chapel Ash, Wolverhampton
1871 ‡FRASER, THOMAS R , M D , F R S E 3 Grosvenor-street, Edinburgh

Year of Election

1876 §Fraser, Rev William, LL D Free Middle Manse, Paisley
1859 *Frazer, Daniel 113 Buchanan-street, Glasgow
1871 ‡Frazer, Evan L R Brunswick-terrace, Spring Bank, Hull
1860 ‡Freeborn, Richard Fernandez 38 Broad street, Oxford
1847 *Freeland, Humphrey William, F G S West street, Chichester, Sussex
1865 ‡Freeman, James 15 Francis-road, Edgbaston, Birmingham
Frere, George Edward, F R S Roydon Hall, Diss, Norfolk
1869 ‡FRERE, The Right Hon Sir H BARTLE E, G C S I, K G C B, F R S, F R G S Wressil Lodge, Wimbledon, S W
1860 ‡Frere, Rev William Edward The Rectory, Bilton, near Bristol
Fripp, George, D, M D
1857. *Frith, Richard Hastings C E, M R I A, F R G S I 48 Summerhill, Dublin
1869 ‡Frodsham, Charles 26 Upper Bedford-place, Russell-square, London, W C
1847 ‡Frost, William Wentworth Lodge, Upper Tulse-hill, London, S W.
1860 *FROUDE, WILLIAM, M A, C E, F R S Chelston Cross, Torquay
1875 ‡Fry, F J 104 Pembroke-road, Clifton, Bristol
Fry, Francis Cotham, Bristol
1875 *Fry, Joseph Storrs 2 Charlotte-street, Bristol
Fry, Richard Cotham Lawn, Bristol
1872 *Fuller, Rev A Ichenor, Chichester
1873 ‡*Fuller, Claude S, R N 44 Holland road, Kensington London, W*
1859 ‡FULLER, FREDERICK M A, Professor of Mathematics in the University and King's College, Aberdeen
1860 ‡FULLER, GEORGE, C E, Professor of Engineering in Queen's College, Belfast 6 College gardens, Belfast
1864 *Furneaux, Rev Alan St German's Parsonage Cornwall

*Gadesden, Augustus William, F S A Ewell Castle, Surrey
1857 ‡Gages, Alphonse, M R I A Museum of Irish Industry, Dublin
1863 *Gainsford, W D Richmond Hill, Sheffield
1876 §Gairdner, Charles Mount Vernon, Shettleston, N B
1850 ‡Gairdner, Professor W T, M D 225 St Vincent-street, Glasgow
1861 ‡Galbraith, Andrew Glasgow
GALBRAITH, Rev J A, M R I A Trinity College, Dublin
1867 ‡Gale, James M 39 Miller street, Glasgow
1863 ‡Gale, Samuel, F C S 338 Oxford-street, London, W
1876 §Gall, James M 23 Miller-street, Glasgow
1861 ‡Galloway, Charles John Knott Mill Iron Works, Manchester
1861 ‡Galloway, John, jun Knott Mill Iron Works, Manchester
1875 §Galloway, W, H M Inspector of Mines Cardiff
1860 *GALTON, Captain DOUGLAS, C B, D C L, F R S, F L S, F G S, F R G S (GENERAL SECRETARY) 12 Chester-street, Grosvenor-place, London, S W
1860 *GALTON, FRANCIS, F R S, F G S, F R G S 42 Rutland-gate, Knightsbridge, London, S W
1860. ‡GALTON, JOHN C, M A, F L S 13 Margaret-street, Cavendish-square, London, W
1870 §Gamble, Lieut-Col D St Helen's, Lancashire
1870 *Gamble, John G, M A 10 Vyvyan-terrace, Clifton, Bristol, and Albion House, Rottingdean, Brighton
1868. ‡GAMGEE, ARTHUR, M D, F R S, F R S E Owens College, Manchester
1862 §GARNER, ROBERT, F L S Stoke-upon-Trent.
1865. §Garner, Mrs Robert. Stoke-upon-Trent.

Year of Election

1842 Garnett, Jeremiah Warren-street, Manchester

1873 ‡Garnham, John 123 Bunhill-row, London, E C

1874 *Garstin, John Ribton, M R I A, F S A Greenhill, Killiney, Co Dublin

1870 ‡Gaskell, Holbrook Woolton Wood, Liverpool

1870 *Gaskell Holbrook jun Mayfield-road, Aigburth Liverpool

1847 *Gaskell, Samuel Windham Club, St James's-square London, S W.

1842 Gaskell Rev William, M A Plymouth-grove, Manchester

1840 ‡GASSIOT, JOHN PETER, D C L, LL D F R S, F C S Clapham Common, London, S W

1862 *Gatty Charles Henry M A F L S F G S Felbridge Park, East Grinstead Sussex

1875 §Gavey J 21 Shrubbery Park West, Clifton, Bristol

1875 §Gaye, Henry S Newton Abbott Devon

1873 ‡Geach R G Cragg Wood, Rawdon Yorkshire

1871 ‡Geddes, John 9 Melville-crescent Edinburgh

1859 ‡Geddes, William D, M A, Professor of Greek, King's College, Old Aberdeen

1854 ‡Gee Robert M D 5 Abercromby-square, Liverpool

1867 §GEIKIE ARCHIBALD LL D F R S L & E F G S Director of the Geological Survey of Scotland Geological Survey Office, Victoria street Edinburgh, and Boroughfield Edinburgh

1871 §Geikie, James F R S L & E, F G S 16 Duncan terrace, Newington, Edinburgh

1855 ‡Gemmell, Andrew 38 Queen street, Glasgow

1875 *George Rev Hereford B, M A, F R G S New College Oxford

1854 ‡Gerard, Henry 8A Rumford-place, Liverpool

1870 ‡Gerstl R University College, London W C

1870 *Gervis, Walter S, M D, F G S Ashburton, Devonshire

1856 *Gething, George Barkley Springfield Newport Monmouthshire

1865 ‡Gibbins, William Battery Works, Digbeth Birmingham

1871 ‡Gibson, Alexander 19 Albany street Edinburgh

1868 ‡Gibson, C M Bethel-street Norwich

1874 ‡Gibson Edward, Q C 23 Fitzwilliam-square Dublin

1876 *Gibson, George A 32 Lauder road Edinburgh

*Gibson, George Stacey Saffron Walden, Essex

1852 ‡Gibson, James 35 Mountjoy-square, Dublin

1870 ‡*Gibson, R E*

1870 ‡Gibson, Thomas 51 Oxford-street, Liverpool

1870 ‡Gibson, Thomas, jun 19 Parkfield-road, Prince's Park, Liverpool.

1867 ‡Gibson, W L, M D Tay-street Dundee

1842 GILBERT, JOSEPH HENRY, Ph D, F R S, F C S Harpenden, near St Albans

1857 ‡Gilbert, J T, M R I A Blackrock, Dublin

1859 *Gilchrist, James, M D Crichton House, Dumfries

Gilderdale, Rev John, M A Walthamstow, Essex, E

Giles, Rev William Netherleigh House near Chester

1871 *Gill, David jun The Observatory, Aberdeen

1868 ‡Gill, Joseph Palermo, Sicily (Care of W H Gill, Esq, General Post Office, St Martin's le-Grand, E C)

1864 ‡GILL, THOMAS 4 Sydney-place, Bath

1861 *Gilroy, George Hindley Hall, Wigan

1867 ‡Gilroy, Robert Craigie, by Dundee

1876 §Gimingham, Charles H 45 St Augustine's-road, Camden-square, London N W

1867 §GINSBURG, Rev C D, D C L, LL D Binfield, Bracknell, Berkshire

1869 ‡Girdlestone, Rev Canon E, M A Halberton Vicarage, Tiverton

Year of Election

1874 *Girdwood, James Kennedy Old Park, Belfast
1860 *Gladstone George, F C S, F R G S 31 Ventnor-villas, Cliftonville, Brighton
1849 *GLADSTONE, JOHN HALL, Ph D F R S, F C S 17 Pembridge-square, Hyde Park, London, W
1861 **Gladstone Murray* *36 Hilton-crescent, London, S W*
1875 *Glaisher, Ernest Henry 1 Dartmouth-place, Blackheath, London S E
1861 *GLAISHER, JAMES, F R S, F R A S 1 Dartmouth-place, Blackheath, London, S E
1871 *GLAISHER, J W L, M A, F R S, F R A S Trinity College, Cambridge
1853 ‡Gleadon, Thomas Ward Mona-buildings, Hull
1870 §Glen, David Corse 14 Annfield-place, Glasgow
1859 ‡Glennie J S Stuart 6 Stone-buildings, Lincoln's-Inn, London, W C
1867 ‡Gloag, John A L 10 Inverleith place, Edinburgh
Glover, George Ranelagh-road, Pimlico London, S W
1874 §Glover George T 30 Donegall place Belfast
Glover, Thomas *Beeley Old Hall, Rowsley Bakewell*
1874 ‡Glover, Thomas 77 Claverton street, London S W
1870 ‡Glynn Thomas R 1 Rodney-street, Liverpool
1872 ‡GODDARD, RICHARD 16 Booth street Bradford, Yorkshire
1852 ‡Godwin, John Wood House, Rostrevor, Belfast
1846 ‡GODWIN AUSTEN, ROBERT A C, B A, F R S, F G S Chilworth Manor, Guildford
1876 §Goff Bruce M D Bothwell, Lanarkshire
GOLDSMID, Sir FRANCIS HENRY, Bart, M P St John's Lodge, Regent's Park, London, N W
1873 §Goldthorp, Miss R I C Cleckheaton, Bradford, Yorkshire
1852 ‡Goodbody, Jonathan Clare, King's County, Ireland
1870 ‡Goodison, George William, C E Gateacre Liverpool
1842 *GOODMAN, JOHN, M D 8 Leicester-street, Southport
1865 ‡Goodman, J D Minories Birmingham
1869 ‡Goodman, Neville Peterhouse, Cambridge
1870 *Goodwin, Rev Henry Albert, M A, F R A S Lambourne Rectory, Romford
1871 *Gordon, Joseph Gordon, F C S 20 King-street, St James's, London, S W
1840 ‡Gordon, Lewis D B Totteridge, Whetstone, London, N
1857 ‡Gordon, Samuel, M D 11 Hume-street, Dublin
1865 ‡Gore George, F R S 50 Islington-row, Edgbaston, Birmingham
1870 ‡Gossage, William Winwood, Woolton, Liverpool
1875 *Gotch, Francis Stokes Croft, Bristol
*Gotch, Rev Frederick William, LL D Stokes Croft, Bristol
*Gotch, Thomas Henry Kettering
1873 §Gott, Charles, M I C E Parkfield-road, Manningham, Bradford.
1849 ‡Gough, The Hon Frederick Perry Hall, Birmingham
1857 ‡Gough, George S, Viscount Rathronan House, Clonmel
1868 §Gould, Rev George Unthank-road, Norwich
GOULD, JOHN, F R S, F L S, F R G S, F Z S 20 Charlotte-street, Bedford-square, London, W C
1854 ‡*Gourlay, Daniel De la C, M D*
1873 ‡Gourlay, J McMillan 21 St Andrew's-place Bradford, Yorkshire.
1867 ‡Gourley, Henry (Engineer) Dundee
1876 §Gow, Robert Cairndowan, Dowanhill, Glasgow
Gowland, James London-wall, London, E C
1873 §Goyder, Dr D Manville-crescent, Bradford, Yorkshire

Year of Election

1861 ‡Grafton, Frederick W Park-road, Whalley Range, Manchester
1867. *GRAHAM, CYRIL F L S, F R G S 9 Cleveland-row, St James's, London, S W
1875 §GRAHAME, JAMES Auldhouse, Pollokshaws, near Glasgow
1852 *Grainger, Rev John, D D, M R I A Skerry and Rathcavan Rectory, Broughshane near Ballymena, Co Antrim
1871 ‡GRANT, Sir ALEXANDER, Bart, M A Principal of the University of Edinburgh 21 Lansdowne crescent Edinburgh
1870 §GRANT, Colonel J A, C B, C S I F R S, F L S, F R G S 10 Upper Grosvenor-street, London, W
1850 ‡Grant, Hon James Cluny Cottage Forres
1855 *GRANT, ROBERT M A, LL D, F R S, F R A S, Regius Professor of Astronomy in the University of Glasgow The Observatory, Glasgow
1854 ‡GRANTHAM, RICHARD B, C E, F G S 22 Whitehall-place, London, S W
1864 ‡Grantham, Richard F 22 Whitehall-place, London, S W
1874 §Graves, Rev James, B A, M R I A Inisnag Glebe, Stoneyford, Co Kilkenny
*Graves, Rev Richard Hastings, D D 31 Raglan-road, Dublin
1864 *Gray, Rev Charles The Vicarage Blyth, Worksop
1865 ‡Gray, Charles Swan bank, Bilston
1870 ‡Gray, C B 5 Rumford place Liverpool
1876 §Gray, Dr Newton terrace Glasgow
1857 ‡Gray, Sir John, M D Rathgar, Dublin
1864 ‡Gray, Jonathan Summerhill House, Bath
1859 ‡Gray, Rev J H Bolsover Castle, Derbyshire
1870 §Gray, J Macfarlane 127 Queens road, Peckham, London S E
1873 §Gray, William, M R I A Mount Charles, Belfast
*GRAY, WILLIAM F G S Gray's court Minster Yard, York
*GRAY, Colonel WILLIAM Farley Hall, near Reading
1854 *Grazebrook, Henry Clent Grove, near Stourbridge, Worcestershire
1866 §Greaves, Charles Augustus, M B, LL B 32 Friar-gate, Derby
1873 ‡Greaves, James H, C E Albert-buildings, Queen Victoria-street, London, E C
1869 §Greaves, William Wellington-circus, Nottingham
1872 §Greaves, William 2 Raymond-buildings, Gray's Inn, London, W C
1872 *Greco, Clair J, LL D Redhill, Surrey
1858 *Greenhalgh, Thomas Thornydikes, Sharples, near Bolton-le-Moors.
1863 ‡Greenwell, G C Poynton, Cheshire
1875 §Greenwood, Frederick School of Medicine, Leeds
1862 *Greenwood, Henry 32 Castle-street, and The Woodlands, Anfield-road, Anfield, Liverpool
1849 ‡Greenwood, William Stones, Todmorden
1861 *GREG, ROBERT PHILIPS, F G S, F R A S Coles Park, Buntingford, Herts
1833 Gregg, T H 22 Ironmonger lane, Cheapside, London, E C
1860 ‡GREGOR, Rev WALTER, M A Pitsligo, Rosehearty, Aberdeenshire
1868 ‡Gregory, Charles Hutton, C E 1 Delahay-street, Westminster, S W
1861 §Gregson, Samuel Leigh Aigburth-road, Liverpool.
1875 ‡Grenfell, J Granville, B A, F G S 5 Albert-villas, Clifton, Bristol
*GRESWELL, Rev RICHARD, M A, F R S, F.R.G S. 39 St. Giles's-street, Oxford

Year of Election

1869 ‡GREY, SIR GEORGE, F R G S Belgrave mansions, Grosvenor-gardens, London, S W
1875 ‡Grey, Mrs Maria G 18 Cadogan place, London S W
1863 ‡Grey, W S Norton, Stockton-on-Tees
1871 *Grierson Samuel Medical Superintendent of the District Asylum, Melrose N B
1859 ‡GRIERSON, THOMAS BOYLE, M D Thornhill Dumfriesshire
1875 §Grieve David, F R S E Hobart House, Dalkeith
1870 ‡Grieve John, M D 21 Lynedock street Glasgow
*Griffin John Joseph F C S 22 Garrick street London, W C
Griffith, Rev C T, D D Elm near Frome Somerset
1859 *GRIFFITH GEORGE, M A, F C S (ASSISTANT GENERAL SECRETARY) Harrow
Griffith George R Fitzwilliam place, Dublin
1868 ‡GRIFFITH, REV JOHN, M A, D C L Findon Rectory, Worthing, Sussex
1870 ‡Griffith, N R The Coppa Mold North Wales
1870 ‡Griffith Rev Henry, F G S Barnet Herts
*GRIFFITH SIR RICHARD JOHN, Bart LL D, F R S E, M R I A, F G S 2 Fitzwilliam place Dublin
1847 ‡Griffith, Thomas Bradford street Birmingham
GRIFFITHS REV JOHN, M A Wadham College, Oxford
1875 ‡Grignon James H M Consul at Riga Riga
1870 ‡Grimsdale T F, M D 29 Rodney street, Liverpool
1842 Grimshaw Samuel M A Errwood Buxton
1864 ‡GROOM-NAPIER, CHARLES OTTLEY, F G S 18 Elgin road, St Peter's Park, London N W
1860 §Grote, Arthur F L S, F G S The Athenaeum Club, Pall Mall, London S W
GROVE THE HON SIR WILLIAM ROBERT, Knt, M A, Ph D, F R S 115 Harley-street, London, W
1863 *GROVES, THOMAS B, F C S 80 St Mary street Weymouth
1860 ‡GRUBB, HOWARD, F R A S 40 Leinster square, Rathmines Dublin
1857 ‡GRUBB, THOMAS, F R S M R I A 141 Leinster road, Dublin
1872 ‡Gruneisen Charles Lewis, F R G S 16 Surrey street, Strand, London W C
Guest, Edwin, M A, LL D, F R S, F L S, F R A S, Master of Caius College, Cambridge Caius Lodge, Cambridge, and Sandford Park, Oxfordshire
1867 ‡Guild, John Bayfield, West Ferry Dundee
Guinness, Henry 17 College-green Dublin
1842 Guinness, Richard Seymour 17 College green Dublin
1856 *GUISE, SIR WILLIAM VERNON, Bart, F G S, F L S Elmore Court, near Gloucester
1862 ‡Gunn, John, M A, F G S Irstead Rectory Norwich
1866 ‡GÜNTHER ALBERT C L G, M A, M D Ph D, F R S, Keeper of the Zoological Collections in the British Museum British Museum, London, W C
1868 *Gurney, John Sprouston Hall, Norwich
1860 *GURNEY, SAMUEL, F L S, F R G S 20 Hanover-terrace, Regent's Park, London, N W
*Gutch, John James Holgate Lodge, York
1876 §Guthrie, Francis Cape Town, Cape of Good Hope
1859 ‡GUTHRIE, FREDERICK, B A, F R S L & E, Professor of Physics in the Royal School of Mines 24 Stanley-crescent, Notting Hill, London, W

Year of Election

1864. §Guyon, George. South Cliff Cottage, Ventnor, Isle of Wight.
1870. ‡*Guyton, Joseph.*
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1870. §Gwyther, R. F. Owens College, Manchester.

Hackett, Michael. Brooklawn, Chapelizod, Dublin.
1865. ‡Hackney, William. 9 Victoria Chambers, Victoria-street, London, S.W.
1866. *Hadden, Frederick J. 3 Park-terrace, Nottingham.
1866. ‡Haddon, Henry. Lenton Field, Nottingham.
Haden, G. N. Trowbridge, Wiltshire.
1842. Hadfield, George. Victoria-park, Manchester.
1870. ‡Hadwen, Isaac. 3 Huskisson-street, Liverpool.
1848. ‡Hadland, William Jenkins. Banbury, Oxfordshire.
1870. ‡Haigh, George. Waterloo, Liverpool.
*Hailstone, Edward, F.S.A. Walton Hall, Wakefield, Yorkshire.
1869. ‡Hake, R. C. Grasmere Lodge, Addison-road, Kensington, London, W.
1875. §Hale, Rev. Edward, M.A., F.G.S., F.R.G.S. Eton College, Windsor.
1870. ‡Halhead, W. B. 7 Parkfield-road, Liverpool.
HALIFAX, The Right Hon. Viscount. 10 Belgrave-square, London, S.W.; and Hickleston Hall, Doncaster.
1872. ‡Hall, Dr. Alfred. 30 Old Steine, Brighton.
1854. *HALL, HUGH FERGIE, F.G.S. Greenheys, Wallasey, Birkenhead.
1859. ‡Hall, John Frederic. Ellerker House, Richmond, Surrey.
1872. *Hall, Captain Marshall. Scientific Club, Savile-row, London, W.
*Hall, Thomas B. Australia. (Care of J. P. Hall, Esq., Crane House, Great Yarmouth.)
1866. *HALL, TOWNSHEND M., F.G.S. Pilton, Barnstaple.
1860. §Hall, Walter. 10 Pier-road, Erith.
1873. §HALLETT, T. G. P., M.A. 52 Redcliffe-hill, Bristol.
1868. *HALLETT, WILLIAM HENRY, F.L.S. Buckingham House, Marine Parade, Brighton.
1861. ‡*Halliday, James. Whalley Cottage, Whalley Range, Manchester.*
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. The Leys, Barrow-on-Soar, near Loughborough.
1866. §HAMILTON, ARCHIBALD, F.G.S. South Barrow, Bromley, Kent.
1865. §Hamilton, Gilbert. Leicester House, Kenilworth-road, Leamington.
HAMILTON, The Very Rev. HENRY PARR, Dean of Salisbury, M.A., F.R.S.L. & E., F.G.S., F.R.A.S. Salisbury.
1869. ‡Hamilton, John, F.G.S. Fyne Court, Bridgewater.
1869. §Hamilton, Roland. Oriental Club, Hanover-square, London, W.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1875. ‡Hancock, C. F., jun., M.A. Royal Institution, Albemarle-street, London, W.
1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
1850. ‡Hancock, John, J.P. The Manor House, Lurgan, Co. Armagh.
1861. ‡Hancock, Walker. 10 Upper Chadwell-street, Pentonville, London, N.
1857. ‡Hancock, William J. 23 Synnot-place, Dublin.
1847. ‡HANCOCK, W. NEILSON, LL.D., M.R.I.A. 64 Upper Gardiner-street, Dublin.
1876. §Hancock, Mrs. W. Neilson. 64 Upper Gardiner-street, Dublin.
1865. ‡Hands, M. Coventry.
Handyside, P. D., M.D., F.R.S.E. Fairmount, Moffat, Dumfriesshire.
1867. ‡Hannah, Rev. John, D.C.L. The Vicarage, Brighton.

Year of Election

1850 ‡Hannay, John Montcoffer House, Aberdeen
1853 ‡Hansell, Thomas T 2 Charlotte-street, Sculcoates, Hull
*HARCOURT, A G VERNON, M A, F R S, F C S 8 Norham-gardens, Oxford
Harcourt, Egerton V Vernon, M A, F G S Whitwell Hall, Yorkshire
1865 ‡Harding, Charles Harborne Heath, Birmingham
1869 ‡Harding, Joseph Hill's Court, Exeter
1869 ‡Harding, William D Islington Lodge, Kings Lynn, Norfolk.
1874 ‡Hardman, E T, F C S 14 Hume-street, Dublin
1872 ‡Hardwicke, Mrs 192 Piccadilly, London, W
*HARE, CHARLES JOHN, M D, Professor of Clinical Medicine in University College, London 57 Brook-street, Grosvenor-square, London, W
Harford, Summers Haverfordwest
1858 ‡Hargrave, James Burley, near Leeds
1876 §Harken, Allen 17 Southgate-street, Gloucester
1853 §HARKNESS, ROBERT, F R S L & E, F G S, Professor of Geology in Queen's College, Cork
1871 §Harkness, William Laboratory, Somerset House, London, W C
1875 *Harland, Rev Albert Augustus, M A The Vicarage, Harefield, Middlesex
1862 *HARLEY, GEORGE, M D, F R S, F C S 25 Harley-street, London, W
*Harley, John Ross Hall, near Shrewsbury
1862 *HARLEY, Rev ROBERT, F R S, F R A S Mill Hill School, Middlesex, and Burton Bank, Mill Hill, Middlesex, N W
1861 ‡Harman, H W, C E 16 Booth-street, Manchester
1868 *HARMER, F W, F G S Oakland House, Cringleford, Norwich
1872 §Harpley, Rev William, M A, F C P S Clayhanger Rectory, Tiverton
*Harris, Alfred Oxton Hall, Tadcaster
*Harris, Alfred, jun Lunefield, Kirkby Lonsdale, Westmoreland
1871 ‡HARRIS, GEORGE, F S A Iselipps Manor, Northolt, Southall, Middlesex
1863 ‡Harris, T W Grange, Middlesborough-on-Tees
1873 ‡Harris, W W Oak villas, Bradford, Yorkshire
1860 ‡Harrison, Rev Francis, M A Oriel College, Oxford
1864 ‡Harrison, George Barnsley, Yorkshire
1873 §Harrison, George, Ph D, F L S, F C S 265 Glossop-road, Sheffield
1874 ‡Harrison, G D B 3 Beaufort-road, Clifton, Bristol
1858 *HARRISON, JAMES PARK, M A Cintra Park Villa, Upper Norwood, S E
1870 ‡HARRISON, REGINALD 51 Rodney-street, Liverpool.
1853 ‡Harrison, Robert 36 George-street, Hull
1863 ‡Harrison, T E. Engineers' Office, Central Station, Newcastle-on-Tyne
1853 *Harrison, William, F S A, F G S Samlesbury Hall, near Preston, Lancashire
1849 ‡HARROWBY, The Right Hon DUDLEY RYDER, Earl of, K G, D C L, F R S, F R G S 39 Grosvenor-square, London, W.; and Sandon Hall, Lichfield
1859 *Hart, Charles Harbourne Hall, Birmingham
1876 *Hart, Thomas Bank View, 33 Preston New-road, Blackburn.
1875 §Hart, W E. Kilberry, near Londonderry
1856 ‡*Hartland, F. Dixon, F S A, F R G S The Oaklands, near Cheltenham.*

Year of
Election

Hartley, James Sunderland
1871 ‡Hartley, Walter Noel, F C S King's College, London, W C
1854 §HARTNUP, JOHN, F R A S Liverpool Observatory, Bidston, Birkenhead
1850 ‡Harvey, Alexander 4 South Wellington-place, Glasgow
1870 ‡Harvey, Enoch Riversdale road, Aigburth, Liverpool
*Harvey, Joseph Charles Knockrea, Douglas-road, Cork
Harvey, J R, M D St Patrick's-place, Cork
1862 *Harwood, John, jun Woodside Mills, Bolton le-Moors
1875 §Hasting, G W Barnard's Green House Malvern
Hastings, Rev H S Martley Rectory, Worcester
1837 †Hastings W Huddersfield
1842 *Hatton, James Richmond House, Higher Broughton, Manchester
1857 ‡HAUGHTON, Rev SAMUEL, M D M A, F R S, M R I A, F G S, Professor of Geology in the University of Dublin Trinity College, Dublin
*Haughton, William 28 City Quay Dublin
1874 ‡*Hawkins, B Waterhouse, F L S, F G S Allison Tower, Dulwich, London S E*
Hawkins John Heywood, M A, F R S, F G S Bignor Park, Petworth, Sussex
1872 *Hawkshaw Henry Paul 20 King street, St James's, London, S W
*HAWKSHAW, Sir JOHN C E F R S, F G S, F R G S Hollycombe, Liphook, Petersfield and 33 Great George street, London, S W
1864 *Hawkshaw, John Clarke, M A, F G S 25 Cornwall gardens, South Kensington, S W, and 33 Great George street, London, S W
1868 §HAWKSLEY, THOMAS, C E, F G S 30 Great George-street, London, S W
1863 ‡Hawthorn William The Cottage Benwell, Newcastle-upon-Tyne
1859 ‡Hay, Sir Andrew Leith, Bart Rannes, Aberdeenshire
1877 §Hay, Arthur J Lerwick Shetland
1861 *HAY, Rear Admiral the Right Hon Sir JOHN C D, Bart, C B, M P, F R S 108 St George's-square, London, S W
1858 †Hay, Samuel Albion-place, Leeds
1867 ‡Hay, William 21 Magdalen-yard road, Dundee
1857 ‡Hayden, Thomas M D 30 Harcourt-street, Dublin
1873 *Hayes, Rev William A, B A 61 George-street, Leeds
1869 ‡Hayward, J High-street, Exeter
1858 *HAYWARD, ROBERT BALDWIN, M A, F R S The Park, Harrow
1851 §HEAD, JEREMIAH, C E, F C S Middlesbrough, Yorkshire
1869 ‡Head, R T The Briars, Alphington, Exeter
1869 ‡Head, W R Bedford-circus, Exeter
1863 ‡Heald, Joseph 22 Leazes terrace, Newcastle-on-Tyne
1872 ‡Healey, C E H Chadwyck 8 Albert-mansions, Victoria-street, London, S W
1871 §Healey, George Matson's, Windermere
1861 *Heape, Benjamin Northwood, Prestwich, near Manchester.
1865 ‡Hearder, William Victoria Parade, Torquay
1866 ‡Heath, Rev D J Esher, Surrey
1863 ‡Heath, G Y, M D Westgate-street, Newcastle-on-Tyne
186 §HEATHFIELD, W E, F C S, F R G S, F R S E 20 King-street, St James's, London, S W
1865 ‡Heaton, Harry Harborne House, Harborne, near Birmingham
1858. *HEATON, JOHN DEAKIN, M D, F R C P. Claremont, Leeds.

Year of Election

1865 ‡*Heaton, Ralph Harborne Lodge, near Birmingham*
1833 ‡HEAVISIDE, Rev Canon J W L, M A The Close, Norwich
1855 ‡HECTOR JAMES M D, F R S, F G S F R G S, Geological Survey of New Zealand Wellington New Zealand
1867 ‡HEDDLE, M FOSTER M D Professor of Chemistry in the University of St Andrews N B
1869 ‡Hedgeland, Rev W J 21 Mount Radford Exeter
1863 ‡Hedley Thomas Cox Lodge, near Newcastle on Tyne
1862 ‡*Helm, George F*
1857 •Hemans George William C E M R I A F G S 1 Westminster-chambers, Victoria street London, S W
1867 ‡Henderson, Alexander Dundee
1845 ‡Henderson, Andrew 120 Gloucester place, Portman-square, London, W
1873 •Henderson, A L 40 King William street London, E C
1866 †*Henderson James jun Dundee*
1874 §Henderson, James Alexander Norwood Tower Belfast
1876 •Henderson William Williamfield Irvine N B
1873 •HENDERSON W D 12 Victoria street Belfast
1856 ‡HENNESSY, HENRY G F R S, M R I A Professor of Applied Mathematics and Mechanics in the Royal College of Science for Ireland Mount Eagle, Sandyford, Co Dublin
1857 ‡Hennessy John Pope, Governor of the Bahamas Government House, Nassau
1873 •Henrici, Olaus M F E, Ph D, F R S, Professor of Mathematics in University College, London 22 Torriano avenue, Camden Town, London N W
Henry, Franklin Portland street, Manchester
Henry, J Snowdon East Dene, Bonchurch, Isle of Wight
Henry, Mitchell, M P Stratheden House, Hyde Park, London, W
1874 ‡HENRY Rev P SHULDAM, D D, M R I A President Queen s College, Belfast
•*Henry, William Charles, M D, F R S, F G S, F R G S, F C S, Haffield, near Ledbury, Herefordshire*
1870 ‡Henty, William Norfolk-terrace, Brighton
1855 •Hepburn, J Gotch, LL B, F C S Sidcup-place, Sidcup, Kent
1855 ‡Hepburn, Robert 9 Portland-place, London, W
Hepburn, Thomas Clapham, London, S W
1871 ‡Hepburn, Thomas H St Mary s Cray, Kent
Hepworth, John Mason Ackworth, Yorkshire
1856 ‡Hepworth Rev Robert 2 St James s square, Cheltenham
•Herbert, Thomas The Park, Nottingham
1852 ‡*Herdman, John*
1866 ‡Herrick, Perry Beau Manor Park, Loughborough
1871 •HERSCHEL, Professor ALEXANDER S, B A, F R A S College of Science, Newcastle on-Tyne,
1874 §Herschel, Major John, R E, F R S Mussoorie, N W P India
1865 ‡Heslop, Dr Birmingham
1863 ‡*Heslop, Joseph*
1873 ‡Heugh, John Gaunt s House, Wimborne, Dorset
1832 ‡Hewitson, William C Oatlands, Surrey
Hey, Rev William, M A, F C P S Clifton, York
1866 •Heymann, Albert. West Bridgford, Nottinghamshire
1866 ‡Heymann, L West Bridgford, Nottinghamshire
1861 •Heywood, Arthur Henry Elleray, Windermere
•HEYWOOD, JAMES, F R.S, F G S, F S A, F R G S, F S S 26 Kensington Palace-gardens, London, W

Year of Election

1861. *Heywood, Oliver. Claremont, Manchester.

Heywood, Thomas Percival. Claremont, Manchester.

1875. ‡Hicks, Henry, F.G.S. Heriot House, Hendon, Middlesex, N.W.

1864. *HIERN, W. P., M.A. 1 Foxton-villas, Richmond, Surrey.

1854. **Higgin, Edward*

1861. *Higgin, James. Lancaster-avenue, Fennel-street, Manchester.

Higginbotham, Samuel. 4 Springfield-court, Queen-street, Glasgow.

1866. ‡Higginbottom, John, F.R.S., F.R.C.S. Gill-street, Nottingham.

1875. ‡Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.

1871. ‡HIGGINS, CLEMENT, B.A., F.C.S. 103 Holland-road, Kensington, London, W.

1861. ‡*Higgins, George*

1854. ‡HIGGINS, Rev. HENRY H., M.A. The Asylum, Rainhill, Liverpool.

1861. *Higgins, James. Stocks House, Cheetham, Manchester.

1870. ‡HIGGINSON, ALFRED. 44 Upper Parliament-street, Liverpool.

Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.

Hill, Arthur. Bruce Castle, Tottenham, London, N.

1872. §Hill, Charles. Rockhurst, West Hoathley, East Grinstead.

*Hill, Rev. Edward, M.A., F.G.S. Sheering Rectory, Harlow.

1857. §Hill, John, M.I.C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.

1871. ‡Hill, Lawrence. The Knowe, Greenock.

*HILL, Sir ROWLAND, K.C.B., D.C.L., F.R.S., F.R.A.S. Hampstead, London, N.W.

1864. ‡*Hill, William. Combe Hay, Bristol.*

1876. §Hill, William H. Barlanark, Shettleston, N.B.

1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.

1871. *Hills, Thomas Hyde. 338 Oxford-street, London, W.

1858. ‡HINCKS, Rev. THOMAS, B.A., F.R.S. Stancliff House, Clevedon, Somerset.

1870. ‡Hinde, G. J. Buenos Ayres.

Hindley, Rev. H. J. Edlington, Lincolnshire.

*Hindmarsh, Luke. Alnbank House, Alnwick.

1865. ‡Hinds, James, M.D. Queen's College, Birmingham.

1863. ‡Hinds, William, M.D. Parade, Birmingham.

1861. *Hinmers, William. Cleveland House, Birkdale, Southport.

1858. ‡Hirst, John, jun. Dobcross, near Manchester.

1861. *HIRST, T. ARCHER, Ph.D., F.R.S., F.R.A.S. Royal Naval College, Greenwich, S.E., and Athenæum Club, Pall Mall, London, S.W.

1856. ‡*Hitch, Samuel, M.D. Sandywell Park, Gloucestershire.*

1870. ‡Hitchman, William, M.D., LL.D., F.L.S. 29 Erskine-street, Liverpool.

*Hoare, Rev. George Tooker. Godstone Rectory, Redhill.

Hoare, J. Gurney. Hampstead, London, N.W.

1864. ‡Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.

1864. ‡Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.

1864. ‡Hobhouse, Henry William. 24 Cadogan-place, London, S.W.

1873. §Hobson, A. S., F.C.S. 3 Upper Heathfield-terrace, Turnham Green, London, W.

1866. ‡HOCKIN, CHARLES, M.D. 8 Avenue-road, St. John's Wood, London, N.W.

1876. §Hodges, Frederick W. Queen's College, Belfast.

1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.

Year of Election

1863 *HODGKIN, THOMAS Benwell Dene, Newcastle-on-Tyne
1873 *Hodgson, George Thornton road, Bradford, Yorkshire
1873 ‡Hodgson, James Oakfield, Manningham, Bradford, Yorkshire
1875 *Hodgson, Kirkman Daniel, M P 67 Brook-street, London, W
1863. ‡Hodgson, Robert Whitburn, Sunderland
1863 ‡Hodgson, R W North Dene, Gateshead
1839 ‡Hodgson, W B, LL D, F R A S, Professor of Commercial and Political Economy in the University of Edinburgh
1865 *HOFMANN, AUGUSTUS WILLIAM, M D, L L D, Ph D, F R S, F C S. 10 Dorotheen Strasse, Berlin
1860 ‡Hogan, Rev A R, M A Watlington Vicarage, Oxfordshire
1870 §Hogg, Robert 54 Jane street, Glasgow
1854 *Holcroft, George Byron's-court, St Mary s-gate, Manchester
1873 *Holden, Isaac Oakworth House, near Keighley, Yorkshire
1856 ‡Holland, Henry Dumbleton, Evesham
1858 §Holland, Loton, F R G S The Gables, Osborne-road, Windsor.
*Holland Philip H 41 Parliament-street, Westminster, S W
1865 ‡Holliday, William New-street, Birmingham
1866 *Holmes, Charles 59 London-road, Derby
1873 ‡Holmes, J R Southbrook Lodge, Bradford, Yorkshire
1876 *Holms, James Hope Park, Partick near Glasgow
1876 §Holms Colonel William, M P Caldwell, Renfrewshire
1870 ‡Holt, William D 23 Edge-lane, Liverpool
*Hone, Nathaniel M R I A Bank of Ireland, Dublin
1875 *Hood, John The Elms Cotham Hill, Bristol
1847 ‡HOOKER, JOSEPH DALTON, C B, M D, D C L, LL D, Pres R S, V P L S, F G S, F R G S Royal Gardens, Kew, Surrey
1865 *Hooper, John P The Hut, Mitcham Common, Surrey
1861 §Hooper, William 7 Pall Mall East, London, S W
1856 ‡Hooton, Jonathan 80 Great Ducie-street, Manchester
1842 Hope, Thomas Arthur Stanton, Bebington, Cheshire
1869 ‡HOPE, WILLIAM, V C Parsloes, Barking, Essex
1865 ‡Hopkins, J S Jesmond Grove, Edgbaston, Birmingham
1870 *Hopkinson, John Woodlea, Beech-lanes Birmingham
1871 §HOPKINSON, JOHN, F G S, F R M S Holly Bank, Watford.
1858 ‡Hopkinson Joseph, jun Britannia Works, Huddersfield
Hornby, Hugh Sandown, Liverpool
1876 *Horne, Robert R 150 Hope-street, Glasgow
1875 *Horniman, F J Surrey House, Forest Hill, London, S E
1854 ‡Horsfall, Thomas Berry Bellamour Park, Rugeley
1856. ‡Horsley, John H 1 Ormond-terrace, Cheltenham
Hotham, Rev Charles, M A, F L S Roos, Patrington, Yorkshire.
1868 ‡Hotson, W C Upper King-street, Norwich
1859 ‡*Hough, Joseph*
HOUGHTON, The Right Hon Lord, M A, D C L, F R.S, F R G S 16 Upper Brook-street, London, W
Houghton, James 41 Rodney-street, Liverpool
1858 ‡Hounsfield, James Hemsworth, Pontefract.
Hovenden, W F, M A Bath
1859 ‡Howard, Captain John Henry, R N The Deanery, Lichfield
1863 ‡Howard, Philip Henry Corby Castle, Carlisle
1876 *Howatt, James 146 Buchanan-street, Glasgow
1857 ‡Howell, Henry H, F G S Museum of Practical Geology, Jermyn-street, London, S W
1868 ‡HOWELL, Rev Canon HINDS Drayton Rectory, near Norwich
1865. *HOWLETT, Rev FREDERICK, F R A S East Tisted Rectory, Alton, Hants

Year of Election.

1863. ‡HOWORTH, H. H. Derby House, Eccles, Manchester.

1854. ‡Howson, The Very Rev. J. S., D.D., Dean of Chester. Chester.

1870. ‡Hubback, Joseph. 1 Brunswick-street, Liverpool.

1835. *HUDSON, HENRY, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.

1842. §Hudson, Robert, F.R.S., F.G.S., F.L.S. Clapham Common, London, S.W.

1867. ‡Hudson, William H. H., M.A. 10 Bennet's-hill, Doctors' Commons, London, E.C., and St. John's College, Cambridge.

1858. *HUGGINS, WILLIAM, D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. Upper Tulse-hill, Brixton, London, S.W.

1857. ‡Huggon, William. 30 Park-row, Leeds.

Hughes, D. Abraham

1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.

1870. *Hughes, Lewis. Fenwick-court, Liverpool.

1876. *Hughes, Thomas Edward. The Priory, Repton, Burton-on-Trent.

1868. §HUGHES, T. M'K., M.A., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.

1863. ‡Hughes, T. W. 4 Hawthorn-terrace, Newcastle-on-Tyne.

1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.

1837. §HULL, EDWARD, M.A., F.R.S., F.G.S. Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.

*Hull, William Darley. Stenton Lodge, Tunbridge Wells.

*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.

1861. ‡HUME, Rev. ABRAHAM, D.C.L., LL.D., F.S.A. All Souls' Vicarage, Rupert-lane, Liverpool.

1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.

1862. *HUMPHRY, GEORGE MURRAY, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Grove Lodge, Cambridge.

1863. *HUNT, AUGUSTUS H., M.A., Ph.D. Birtley House, near Chester-le-Street.

1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.

1840. ‡HUNT, ROBERT, F.R.S., Keeper of the Mining Records. Museum of Practical Geology, Jermyn-street, London, S.W.

1864. ‡Hunt, W. 72 Pulteney-street, Bath.

1875. *Hunt, William. The Woodlands, Tyndall's Park, Clifton, Bristol.

Hunter, Andrew Galloway. Denholm, Hawick, N.B.

1868. ‡Hunter, Christopher. Alliance Insurance Office, North Shields.

1867. ‡Hunter, David. Blackness, Dundee.

1869. *Hunter, Rev. Robert, F.G.S. 9 Mecklenburgh-street, London, W.C.

1855. *Hunter, Thomas O. 13 William-street, Greenock.

1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.

1875. §Hurnard, James. Lexden, Colchester, Essex.

1869. ‡Hurst, George. Bedford.

1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.

1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.

Husband, William Dalla. Coney-street, York.

1876. §Hutchinson, John. 22 Hamilton Park-terrace, Glasgow.

1874. ‡Hutchinson, Thomas J., F.R.G.S. Chimoo Cottage, Mill Hill, London, N.W.

1876. §Hutchison, Peter. 28 Berkeley-terrace, Glasgow.

1868. *Hutchison, Robert, F.R.S.E. Carlowrie, Kirkliston, N.B.

1863. ‡HUTT, The Right Hon. Sir W., K.C.B. Gibside, Gateshead.

Year of Election

Hutton, Crompton Putney Park, Surrey, S W
1864 *Hutton, Darnton (Care of Arthur Lupton, Esq, Headingley, near Leeds)
Hutton, Henry Edenfield Dundrum, Co Dublin
1857 ‡Hutton, Henry D 10 Lower Mountjoy street Dublin
1861 *Hutton, T Maxwell Summerhill, Dublin
1852 ‡HUXLEY, THOMAS HENRY, Ph D, LL D, Sec R S, F L S, F G S, Professor of Natural History in the Royal School of Mines 4 Marlborough-place London N W
Hyde, Edward Dukinfield, near Manchester
1871 *Hyett, Francis A 13 Hereford square Old Brompton London, S W
Hyett, William Henry, F R S Painswick House, Painswick, near Stroud, Gloucestershire

Ihne, William, Ph D Heidelberg
1873 §Ikin, J I 19 Park-place Leeds
1861 ‡Iles, Rev J H Rectory, Wolverhampton
1858 ‡Ingham Henry Wortley near Leeds
1876 §Inglis, Anthony Broomhill, Partick, Glasgow
1871 ‡INGLIS, The Right Hon JOHN, D C L, LL D, Lord Justice General of Scotland Edinburgh
1876 §Inglis, John, jun Prince's-terrace Dowanhill, Glasgow
1858 *Ingram, Hugo Francis Meynell Temple Newsam, Leeds
1852 ‡INGRAM, J K, LL D, M R I A, Regius Professor of Greek Trinity College, Dublin.
1870 *Inman, William Upton Manor Liverpool
Ireland, R S M D 121 Stephen's-green, Dublin
1857 ‡Irvine, Hans M A, M B 1 Rutland square, Dublin
1862 ‡ISELIN, J F, M A, F G S 52 Stockwell Park-road, London, S W
1863. *Ivory, Thomas 23 Walker-street, Edinburgh

1865 ‡Jabet, George Wellington road Handsworth, Birmingham
1870 ‡Jack, James 26 Abercromby square Liverpool
1859 ‡Jack, John, M A Belhelvie-by-Whitecairns, Aberdeenshire
1876 §Jack, William 19 Lansdowne road, Notting Hill, London, W
1866 ‡Jackson, H W, F R A S, F G S 15 The Terrace, High road, Lewisham, S E
1869. §Jackson, Moses The Vale, Ramsgate
Jackson, Professor Thomas LL D St Andrews, Scotland
1863 *Jackson-Gwilt, Mrs H Moonbeam Villa, The Grove, New Wimbledon, London, S W
1852 ‡JACOBS, BETHEL 40 George-street, Hull
1874 *Jaffe, John Cambridge Villa, Strandtown, near Belfast
1865 *Jaffray, John Park-grove, Edgbaston Birmingham
1872 ‡James, Christopher 8 Laurence Pountney Hill, London, E C
1859. ‡James, Edward 9 Gascoyne terrace, Plymouth
1860 ‡James, Edward H 9 Gascoyne-terrace, Plymouth
JAMES, Major-General Sir HENRY, R E, F R S, F G S, M R I A Topographical Depôt, 4 New street, London, S W
1863 *JAMES, Sir WALTER, Bart, F G S 6 Whitehall gardens, London, S W
1875 ‡James, Rev William Harley Lodge, Clifton, Bristol
1858. ‡James, William C 9 Gascoyne-terrace, Plymouth
1863 ‡*Jameson, John Henry 10 Catherine Terrace, Gateshead.*
1876 §Jamieson, J L K. The Mansion House, Govan, Glasgow
1870. §Jamieson, Rev Dr R 156 Randolph-terrace, Glasgow

Year of
Election.

1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. ‡Jardine, Alexander. Jardine Hall, Lockerby, Dumfriesshire.
1870. ‡Jardine, Edward. Beach Lawn, Waterloo, Liverpool.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
JARRETT, Rev. THOMAS, M.A., Professor of Arabic in the University of Cambridge. Trunch, Norfolk.
1870. §Jarrold, John James. London-street, Norwich.
1862. ‡Jeakes, Rev. James, M.A. 54 Argyll-road, Kensington, W.
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1868. ‡Jecks, Charles. 20 Langham-place, Northampton.
1870. ‡*Jeffery, F. J.*
1856. ‡Jeffery, Henry, M.A. 438 High-street, Cheltenham.
1855. *Jeffray, John. Cardowan House, Millerston, Glasgow.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. 5 Brick-court, Temple, E.C.
1861. *JEFFREYS, J. GWYN, LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S. Ware Priory, Herts.
1852. ‡JELLETT, Rev. JOHN H., M.A., M.R.I.A., Professor of Natural Philosophy in Trinity College, Dublin. 64 Upper Leeson-street, Dublin.
1842. Jellicorse, John. Chaseley, near Rugeley, Staffordshire.
1862. §JENKIN, H. C. FLEEMING, F.R.S., M.I.C.E., Professor of Civil Engineering in the University of Edinburgh. 3 Great Stuart-street, Edinburgh.
1864. §JENKINS, Captain GRIFFITH, C.B., F.R.G.S. Little Garth, Welshpool.
1873. §Jenkins, Major General J. J. 14 St. James's-square, London, S.W.
*Jenkyns, Rev. Henry, D.D. The College, Durham.
Jennette, Matthew. 106 Conway-street, Birkenhead.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1872. ‡Jennings, W. Grand Hotel, Brighton.
1870. ‡Jerdon, T. C. (Care of Mr. H. S. King, 45 Pall Mall, London, S.W.)
*Jerram, Rev. S. John, M.A. Chobham Vicarage, near Bagshot, Surrey.
1872. ‡Jesson, Thomas. 7 Upper Wimpole-street, Cavendish-square, London, W.
Jessop, William, jun. Butterley Hall, Derbyshire.
1870. *JEVONS, W. STANLEY, M.A., LL.D., F.R.S., Professor of Political Economy in University College, London. The Chesnuts, Branch Hill, Hampstead Heath, London, N.W.
1872. *Joad, George C. Oakfield, Wimbledon, Surrey, S.W.
1871. *Johnson, David, F.C.S., F.G.S. Irvon Villa, Grosvenor-road, Wrexham.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1875. §Johnson, James Henry, F.G.S. 3 Queen's-road, Southport.
1866. §Johnson, John. Knighton Fields, Leicester.
1866. ‡Johnson, John G. 18A Basinghall-street, London, E.C.
1868. ‡Johnson, J. Godwin. St. Giles's-street, Norwich.
1872. ‡Johnson, J. T. 27 Dale-street, Manchester.
1861. ‡Johnson, Richard. 27 Dale-street, Manchester.
1870. §Johnson, Richard C. 28 Marine-crescent, Waterloo, near Liverpool.
1833. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
*Johnson, Thomas. The Hermitage, Frodsham, Cheshire.
1864. ‡*Johnson, Thomas.*
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham.
1871. ‡Johnston, A. Keith, F.R.G.S. 1 Savile-row, London, W.
1864. ‡Johnston, David. 13 Marlborough-buildings, Bath.

Year of Election

1864 ‡*Johnston, Edward*
1859 ‡Johnston, James Newmill Elgin, N B
1864 ‡Johnston, James Manor House, Northend, Hampstead, London, N W
1876 §Johnston, John, M D Edinburgh
*Johnstone James Alva House Alva by Stirling N B
1864 ‡Johnstone John 1 Barnard villas, Bath
1876 §Johnstone, William 5 Woodside terrace, Glasgow
1864 ‡Jolly, Thomas Park View villas, Bath
1871 §Jolly, William (H M Inspector of Schools) Inverness, N B
1849 ‡Jones, Baynham Selkirk Villa Cheltenham
1856 ‡Jones, C W 7 Grosvenor place, Cheltenham
1854 ‡*Jones, Rev Henry H*
1854 ‡*Jones, John*
1864 §JONES, JOHN, F G S Saltburn-by-the-Sea, Yorkshire
1865 ‡Jones, John 40 Union passage Birmingham
*Jones, Robert 2 Castle street Liverpool
1873 ‡Jones, Theodore B 1 Finsbury circus London, E C
1860 ‡JONES, THOMAS RUPERT, F R S , F G S , Professor of Geology and Mineralogy, Royal Military and Staff Colleges, Sandhurst 5 College-terrace, York Town, Surrey
1847 ‡JONES, THOMAS RYMER, F R S 52 Cornwall-road, Westbourne Park, London, W
1864 §JONES SIR WILLOUGHBY, Bart ,F R G S Cranmer Hall, Fakenham, Norfolk
1875 *Jose J E 3 Queen-square, Bristol
*Joule, Benjamin St John B 28 Leicester-street, Southport, Lancashire
1842 *JOULE, JAMES PRESCOTT, LL D , F R S , F C S 343 Lower Broughton-road, Manchester
1847 ‡JOWETT Rev B , M A , Regius Professor of Greek in the University of Oxford Balliol College, Oxford
1858 ‡Jowett, John Leeds
1872 ‡Joy, Algernon 17 Parliament street, Westminster, S W
1848 *Joy, Rev Charles Ashfield Grove Parsonage, Wantage, Berkshire
Joy, Rev John Holmes, M A 9 Coloney-terrace, Tunbridge Wells
*Jubb, Abraham Halifax
1870 ‡Judd, John Wesley, F G S 0 Manor-view, Brixton, London, S W
1863 ‡*Jukes, Rev Andrew Spring Bank, Hull*

1868 *Kaines, Joseph, M A , D Sc 13 Finsbury place South, London, E C
KANE, SIR ROBERT, M D , F R S , M R I A , Principal of the Royal College of Cork 51 Stephen s-green, Dublin
1857 ‡Kavanagh, James W Grenville, Rathgar, Ireland
1859 ‡Kay, David, F R G S 19 Upper Phillimore-place, Kensington, London, W
Kay, John Cunliff Fairfield Hall, near Skipton
*Kay, John Robinson Walmersley House, Bury, Lancashire
Kay, Robert Haugh Bank, Bolton-le-Moors
1847 *Kay, Rev William, D D Great Leghs Rectory, Chelmsford
1850 ‡Kay-Shuttleworth, Sir James, Bart Gawthorpe, Burnley
1872 ‡Keames, William M 5 Lower-rock-gardens, Brighton
1855 ‡*Keddie, William*
1875 ‡Keeling, George William Tuthill, Lydney
1866. ‡Keene, Alfred Eastnoor House, Leamington
1850 ‡KELLAND, Rev PHILIP, M A., F R.S L & E , Professor of Mathematics in the University of Edinburgh. 20 Clarendon-crescent, Edinburgh

Year of Election

1876 §Kelly, Andrew G The Manse, Alloa, N B
1864 *Kelly, W M, M D 11 The Crescent, Taunton, Somerset
1853 ‡Kemp, Rev Henry William, B A The Charter House, Hull
1875 §KENNEDY, ALEXANDER B W, C E, Professor of Engineering in University College, London 9 Bartholomew road, London, N W
1876 §Kennedy, Hugh Redclyffe, Partickhill, Glasgow
1867 ‡*Kennedy, Lieut Colonel John Pitt 20 Torrington square, Bloomsbury, London, W C*
1865 ‡Kenrick, William Norfolk road, Edgbaston, Birmingham
Kent, J C Levant Lodge, Earls Croome, Worcester
1857 ‡Kent, William T, M R D S 51 Rutland square, Dublin
1857 ‡Kenworth, James Ryley 7 Pembroke-place, Liverpool
1857 *Ker, André Allen Murray Newbliss House, Newbliss, Ireland.
1855 *Ker, Robert Dougalston, Milngavie, N B
1876 §Ker, William 1 Windsor terrace West, Glasgow
1868 ‡Kerrison, Roger Crown Bank, Norwich
1869 *Kesselmeyer, Charles A 1 Peter street, Manchester
1869 *Kesselmeyer, William Johannes 1 Peter street, Manchester
1861 *Keymer, John Parker street, Manchester
1876 §Kidston, J B West Regent street, Glasgow
1876 §Kidston, William Ferniegair, Helensburgh, N B
1865 *Kinahan, Edward Hudson 11 Merrion square North, Dublin
1860 ‡KINAHAN, G HENRY, M R I A, Geological Survey of Ireland 14 Hume street, Dublin
1858 ‡*Kincaid, Henry Ellis, M A 8 Lyddon terrace, Leeds*
1875 *Kinch, Edward, F C S Agricultural College, Home Department, Tokio, Japan (Care of C J Kinch, Esq, Eaton Hastings, Lechlade, Gloucestershire)
1872 *King, Mrs E M 34 Cornwall road, Westbourne Park, London, W
1875 *King, F Ambrose Avonside, Clifton, Bristol
1871 *King, Herbert Poole Theological College, Salisbury
1855 ‡King, James Levernholme, Hurlet, Glasgow
1870 §King, John Thomson, C E 4 Clayton-square, Liverpool
King, Joseph Blundell Sands, Liverpool
1864 §KING, KELBURNE, M D 27 George street, and Royal Institution, Hull
1860 *King, Mervyn Kersteman 10 Vyvyan-terrace, Clifton, Bristol
1875 *King, Percy L Avonside, Clifton, Bristol
King, Rev Samuel, M A, F R A S St Aubin's, Jersey
1870 ‡King, William 13 Adelaide terrace, Waterloo, Liverpool
King, William Poole, F G S Avonside, Clifton, Bristol
1869 ‡Kingdon, K Taddiford, Exeter
1861 ‡Kingsley, John Ashfield, Victoria Park, Manchester
1876 §Kingston, Thomas Strawberry House, Chiswick, Middlesex
1835 Kingstone, A John, M A Mosstown, Longford, Ireland
1875 §Kingzett, Charles T, F C S 23 Shaftesbury terrace, Warwick-road, Kensington, London, W
1867 ‡Kinloch, Colonel Kirriemuir, Logie, Scotland
1867 *KINNAIRD, The Hon ARTHUR FITZGERALD, M P 1 Pall Mall East, London, S W, and Rossie Priory, Inchture, Perthshire
1863 ‡KINNAIRD, The Right Hon Lord, K T, F G S Rossie Priory, Inchture, Perthshire
Kinnear, J G, F R S E
1870 ‡Kinsman, William R. Branch Bank of England, Liverpool.
1863 ‡Kirkaldy, David 28 Bartholomew-road North, London, N W.
1860 ‡KIRKMAN, Rev THOMAS P, M A, F R S Croft Rectory, near Warrington

Year of Election.

Kirkpatrick, Rev. W. B., D.D. 48 North Great George-street, Dublin.
1876. *Kirkwood, Anderson, LL.D. 12 Windsor-terrace West, Hillhead, Glasgow
1875 §Kirsop, John 6 Queen's-crescent, Glasgow
1870. ‡Kitchener, Frank E. Rugby.
1869. ‡Knapman, Edward The Vineyard, Castle-street, Exeter.
1870 §Kneeshaw, Henry 2 Gambier-terrace, Liverpool.
1838 Knipe, J. A. Botcherby, Carlisle
1872 *Knott, George, LL.B., F.R.A.S. Cuckfield, Hayward's Heath, Sussex
1873. *Knowles, George Moorhead, Shipley, Yorkshire
1872. ‡Knowles, James The Hollies, Clapham Common, S.W.
1842 Knowles, John. Old Trafford Bank House, Old Trafford, Manchester.
1870. ‡*Knowles, Rev. J. L.*
1874. §Knowles, William James Cullybackey, Belfast, Ireland
1876 §Knox, David N., M.A., M.B. 8 Belgrave-terrace, Hillhead, Glasgow.
*Knox, George James. 2 Portland-terrace, Regent's Park, London, N.W.
1835. Knox, Thomas B. Union Club, Trafalgar-square, London, W.C.
1875. *Knubley, E. P. Steeple Ashton Vicarage, Trowbridge
1870 ‡Kynaston, Josiah W. St. Helens, Lancashire
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.

1858. §Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1862. ‡*Lackerstein, Dr*
1859. §Ladd, William, F.R.A.S. 11 & 13 Beak-street, Regent-street, London, W.
1850. ‡Laing, David, F.S.A. Scotl. Signet Library, Edinburgh.
1870. ‡Laird, H. H. Birkenhead.
Laird, John, M.P. Hamilton-square, Birkenhead
1870. §Laird, John, jun. Grosvenor-road, Claughton, Birkenhead
1859. ‡Lalor, John Joseph, M.R.I.A. 2 Longford-terrace, Monkstown, Co. Dublin
1846. *Laming, Richard. High-street, Arundel.
1870. ‡Lamport, Charles. Upper Norwood, Surrey, S.E.
1871. ‡Lancaster, Edward Karesforth Hall, Barnsley, Yorkshire.
1859. ‡Lang, Rev. John Marshall Bank House, Morningside, Edinburgh.
1864. §Lang, Robert. Mancombe, Henbury, Bristol
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool
*Langton, William. Docklands, Ingatestone, Essex.
1865. ‡LANKESTER, E. RAY, M.A., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London. Exeter College, Oxford
Lanyon, Sir Charles. The Abbey, White Abbey, Belfast.
*LARCOM, Major-General Sir THOMAS AISKEW, Bart., K.C.B., R.E., F.R.S., M.R.I.A. Heathfield House, Fareham, Hants
LASSELL, WILLIAM, F.R.S., F.R.A.S. Ray Lodge, Maidenhead.
1861. *Latham, Arthur G. Lower King-street, Manchester
1870. *Latham, Baldwin. 7 Westminster-chambers, Westminster, S.W.
1870. ‡Laughton, John Knox, M.A., F.R.A.S., F.R.G.S. Royal Naval College, Portsmouth.
1875. ‡Lavington, William F. 107 Pembroke-road, Clifton, Bristol.
1870. *Law, Channell 5 Champion-park, Camberwell, London, S.E.
1857. ‡Law, Hugh, Q.C. 4 Great Denmark-street, Dublin.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
Lawley, The Hon. Francis Charles. Escrick Park, near York.
Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.

Year of Election.

1875 ‡Lawson, George, Ph D, LL D, Professor of Chemistry and Botany, Halifax, Nova Scotia.

1869 ‡*Lawson, Henry* 8 *Nottingham place, London, W*

1857 ‡Lawson, The Right Hon James A, LL D, M R I A 27 Fitzwilliam-street, Dublin

1876 §Lawson, John Cluny Hill, Forres, N B

1868 *LAWSON, M. ALEXANDER, M A, F L S, Professor of Botany in the University of Oxford Botanic Gardens, Oxford

1863 ‡Lawton, Benjamin C Neville Chambers, 44 Westgate-street, Newcastle-upon-Tyne

1853 ‡Lawton, William 5 Victoria terrace, Derringham, Hull

1865 ‡Lea, Henry 35 Paradise street, Birmingham

1857 ‡Leach, Capt R L Mountjoy Phœnix Park, Dublin

1870 *Leaf, Charles John, F L S, F G S, F S A Old Change, London, E C, and Painshill, Cobham

1847 *LEATHAM, EDWARD ALDAM, M P Whitley Hall, Huddersfield and 46 Eaton square, London, S W

*Leather, John Towlerton, F S A Leventhorpe Hall, near Leeds

1858 ‡Leather, John W Newton Green, Leeds

1863 ‡Leavers, J W The Park, Nottingham

1872 ‡LEBOUR, G A, F G S Weedpark House, Dipton, Lintz Green, Co Durham

1858 *Le Cappelain, John Wood-lane, Highgate, London, N

1858 ‡Ledgard, William Potter Newton, near Leeds

1842 Lee, Daniel Springfield House, Pendlebury, Manchester

1861 ‡Lee, Henry Irwell House, Lower Broughton, Manchester

1853 *LEE, JOHN EDWARD, F G S, F S A Villa Syracusa, Torquay

1859 ‡Lees, William Link Vale Lodge, Viewforth, Edinburgh

*Leese, Joseph Glenfield, Altrincham, Manchester

*Leeson, Henry B, M A, M D, F R S, F C S The Maples, Bonchurch, *Isle of Wight*

1872 ‡LEFEVRE, G SHAW, M P, F R G S 18 Spring-gardens, London, S W

*LEFROY, Major-General J HENRY, C B, R A, F R S, F R G S, Governor of Bermuda. Bermuda

*Legh, Lieut.-Colonel George Cornwall, M P High Legh Hall, Cheshire, and 43 Curzon-street, Mayfair, London, W

1869 ‡Le Grice, A J Trereife, Penzance

1868 ‡LEICESTER, The Right Hon the Earl of Holkham, Norfolk

1856 ‡LEIGH, The Right Hon Lord, D C L 37 Portman-square, London, W, and Stoneleigh Abbey, Kenilworth

1861 **Leigh, Henry Moorfield, Swinton, near Manchester*

1870 ‡Leighton, Andrew 35 High-park street, Liverpool

1867 *§Leishman, James Gateacre Hall, Liverpool*

1870 ‡Leister, G F Gresbourn House, Liverpool

1859 ‡Leith, Alexander Glenkindie, Inverkindie, N B

1863 *LENDY, Captain AUGUSTE FREDERIC, F L.S, F G S Sunbury House, Sunbury, Middlesex

1867. ‡Leng, John 'Advertiser' Office, Dundee

1861 ‡Lennox, A. C W 7 Beaufort-gardens, Brompton, London, S W.

Lentaigne, John, M D Tallaght House, Co Dublin; and 14 Great Dominick-street, Dublin

Lentaigne, Joseph 12 Great Denmark-street, Dublin

1871 §LEONARD, HUGH, F G S, M.R I A., F R G S I. Geological Survey of Ireland, 14 Hume-street, Dublin

1874 ‡Lepper, Charles W Laurel Lodge, Belfast.

1861 ‡Leppoc, Henry Julius, Kersal Crag, near Manchester,

Year of
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1872 §Lermit, Rev Dr School House, Dedham
1871 ‡Leslie, Alexander C E 72 George street, Edinburgh
1856 ‡Leslie, Colonel J Forbes Rothienorman Aberdeenshire
1852 ‡LESLIE T E CLIFFE LL B Professor of Jurisprudence and Political Economy, Queen's College Belfast
1876 §Leveson Edward John Cluny Sydenham Hill Glasgow
1866 §LEVI Dr LEONE, F S A, F S S, F R G S, Professor of Commercial Law in King's College, London 5 Crown Office-row, Temple, London, E C
1870 ‡Lewis Alfred Lionel 151 Church road, De Beauvoir Town, London, N
1853 ‡Liddell, George William Moore Sutton House near Hull
1860 ‡LIDDELL, The Very Rev H G, D D Dean of Christ Church, Oxford
1855 ‡*Liddell John*
1876 §Lietke J O 30 Gordon-street, Glasgow
1859 ‡*Ligertwood, George*
1864 ‡LIGHTBODY ROBERT F G S Ludlow, Salop
1862 ‡LILFORD, The Right Hon Lord, F L S Lilford Hall, Oundle, Northamptonshire
*LIMERICK CHARLES GRAVES D D M R I A, Lord *Bishop of* The Palace Henry street, Limerick
*Lindsay, Charles Ridge Park, Lanark, N B
1855 **Lindsay John H*
1871 *LINDSAY The Right Hon Lord M P 47 Brook street, London, W
1871 ‡*Lindsay Rev T M 7 Great Stuart street, Edinburgh*
1870 ‡Lindsay, Thomas F C S 288 Renfrew street Glasgow
1842 **Lingard John R F G S Mayfield, Shortlands Bromley, Kent*
Lingwood, Robert M, M A, F L S, F G S 1 Derby-villas, Cheltenham
1876 §Linn, James Livingstone, Mid-Calder, N B
Lister, James Liverpool Union Bank, Liverpool
1873 **Lister, Samuel Cunliffe Farfield Hall, Addingham, Leeds.*
1870 §Lister, Thomas Victoria-crescent, Barnsley, Yorkshire
1876 §Little, Thomas Evelyn 42 Brunswick-street, Glasgow
Littledale, Harold Liscard Hall, Cheshire
1861 *LIVEING, G D M A F C S Professor of Chemistry in the University of Cambridge Cambridge
1876 *Liversidge, Archibald F C S F G S The University, Sydney (Care of Mr Bain, 1 Haymarket London, W)
1864 §Livesay, J G Cromarty House Ventnor, Isle of Wight
1860 ‡*Livingstone, Rev Thomas Gott, Minor Canon of Carlisle Cathedral*
Lloyd, Rev A R Hengold, near Oswestry
Lloyd, Rev C, M A Whittington, Oswestry
1842 Lloyd, Edward King street, Manchester
1865 ‡Lloyd, G B Edgbaston-grove, Birmingham
*Lloyd, George, M D, F G S Park Glass Works, Birmingham
*LLOYD, Rev HUMPHREY, D D, LL D, F R S L & E, M R I A, Provost of Trinity College, Dublin
1870 ‡Lloyd, James 16 Welfield-place, Liverpool
1870 ‡Lloyd, J H, M D Anglesey, North Wales
1865 ‡Lloyd, John Queen's College, Birmingham
Lloyd, Rev Rees Lewis Belper, Derbyshire
1865 *Lloyd, Wilson Myrod House, Wednesbury
1854 *LOBLEY, JAMES LOGAN, F G S, F R G S 59 Clarendon-road, Kensington, London, W
1853 *Locke, John. 133 Leinster-road, Dublin.

Year of
Election
1867 *Locke, John. 83 Addison road, Kensington, London, W.
1872 ‡LOCKE, JOHN, M.P. 63 Eaton place, London, S.W.
1863 ‡LOCKYER, J. NORMAN, F.R.S., F.R.A.S. 16 Penywern-road, South Kensington, London, S.W.
1875 *Lodge, Oliver J., B.Sc. The Watland, Longport, Staffordshire.
1868 ‡Login, Thomas, C.E., F.R.S.E. India.
1862 †Long, Andrew, M.A. King's College, Cambridge.
1876 §Long, H. A. Charlotte-street, Glasgow.
1872 ‡Long, Jeremiah. 50 Marine Parade, Brighton.
1871 *Long, John Jex. 727 Duke-street, Glasgow.
1851 ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1866 §Longdon, Frederick. Luamlin, near Derby.
1857 †Longfield, Rev. George, D.D. Trinity College, Dublin.
LONGFIELD, MOUNTIFORT, LL.D., M.R.I.A., Regius Professor of Feudal and English Law in the University of Dublin. 47 Fitzwilliam square, Dublin.
1861 *Longman, William, F.G.S. 36 Hyde Park square, London, W.
1859 ‡Longmuir, Rev. John, M.A., LL.D. 14 Silver-street, Aberdeen.
Longridge, William S. Boyn Grove, Maidenhead, Berks.
1875 *Longstaff, George Blundell, M.A., M.B., F.C.S. Southfield Grange, Wandsworth, S.W.
1871 §Longstaff, George Dixon, M.D., F.C.S. Southfields, Wandsworth, S.W.; and 9 Upper Thames street, London, E.C.
1872 *Longstaff, Lieut.-Colonel Llewellyn Wood, F.R.G.S. Reform Club, Pall Mall, London, S.W.
1875 §Lonsdale, N. Lowenthal. The Firs, Westbury Park, Redlands, Bristol.
1861 *Lord, Edward. Adamroyd, Todmorden.
1863 ‡Losh, W. S. Wreay Syke, Carlisle.
1876 *Love, James, F.R.A.S. Talbot Lodge, Bickerton-road, Upper Holloway, London, N.
1875 *Lovett, W. J. 96 Lionel-street, Birmingham.
1867 *Low, James F. Monifieth, by Dundee.
1863 *Lowe, Lieut.-Colonel Arthur S. H., F.R.A.S. 76 Lancaster-gate, London, W.
1861 *LOWE, EDWARD JOSEPH, F.R.S., F.R.A.S., F.L.S., F.G.S., F.M.S. Highfield House Observatory, near Nottingham.
1870 ‡Lowe, G. C. 67 Cecil-street, Greenheys, Manchester.
1868 ‡Lowe, John, M.D. King's Lynn.
1850 ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1853 *LUBBOCK, Sir JOHN, Bart., M.P., F.R.S., F.L.S., F.G.S. High Elms, Farnborough, Kent.
1870 ‡Lubbock, Montague. High Elms, Farnborough, Kent.
1849 *Luckcock, Howard. Oak hill, Edgbaston, Birmingham.
1875 §Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1867 *Luis, John Henry. Cidhmore, Dundee.
1873 ‡Lumley, J. Hope Villa, Thornbury, near Bradford, Yorkshire.
1866 *Lund, Charles. 48 Market-street, Bradford, Yorkshire.
1873 †Lund, Joseph. Ilkley, Yorkshire.
1850 *Lundie, Cornelius. Tweed Lodge, Charles-street, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1858 *Lupton, Arthur. Headingley, near Leeds.
1864 *Lupton, Darnton. The Harehills, near Leeds.
1874 *Lupton, Sydney. Harrow.
1864 *Lutley, John. Brockhampton Park, Worcester.
1866. ‡LYCETT, Sir FRANCIS. 18 Highbury-grove, London, N.

Year of
Election.

1871. ‡Lyell, Leonard. 42 Regent's Park-road, London, N.W.
1874. ‡Lynam, James, C E. Ballinasloe, Ireland.
1857. ‡Lyons, Robert D , F R C P.I 8 Merrion-square West, Dublin.
1862. *Lyte, F Maxwell, F.C S. 6 Cité de Retiro, Faubourg St Honoré, Paris.

1852. ‡MacAdam, Robert. 18 College-square East, Belfast.
1854. *Macadam, Stevenson, Ph D , F.R S E , F.C.S , Lecturer on Chemistry Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1876. §M'Adam, William. 30 St Vincent-crescent, Glasgow
1876 *Macadam, William Ivison Surgeons' Hall, Edinburgh.
1868. ‡Macalister, Alexander, M D , Professor of Zoology in the University of Dublin 13 Adelaide-road, Dublin
1868. ‡M'Allan, W. A. Norwich
1866. *M'Arthur, A., M.P. Raleigh Hall, Brixton Rise, London, S W
1840. Macaulay, James A. M , M.D 22 Cambridge-road, Kilburn, London, N.W.
1871 ‡M'Bain, James, M D , R N. Logie Villa, York-road, Trinity, Edinburgh.
*MacBrayne, Robert. Messrs. Black and Wingate, 5 Exchange-square, Glasgow.
1866 ‡M'Callan, Rev. J. F., M A Basford, near Nottingham.
1855. ‡*M'Callum, Archibald K , M A*
1863. ‡M'Calmont, Robert. Gatton Park, Reigate.
1855. ‡M'Cann, Rev. James, D D , F G S 18 Shaftesbury-terrace, Glasgow
1876. *M'Clelland, A. S. 4 Crown-gardens, Dowanhill, Glasgow
1840 M'Clelland, James, F S S 32 Pembridge-square, London, W.
1868 ‡M'Clintock, Rear-Admiral Sir Francis L , R N , F R.S , F R G S. United Service Club, Pall Mall, London, S W
1872. *McClure, J H. 10 Esplanade, Waterloo, Liverpool.
1874. ‡M'Clure, Sir Thomas, Bart. Belmont, Belfast.
*M'Connel, James. Moore-place, Esher, Surrey.
1859. *M'Connell, David C , F G S. 44 Manor-place, Edinburgh.
1858. ‡M'Connell, J. E Woodlands, Great Missenden
1876. §M'Culloch, Richard. 109 Douglas-street, Blythswood-square, Glasgow.
1871. ‡M'Donald, William. Yokohama, Japan. (Care of R. K. Knevitt, Esq., Sun-court, Cornhill, E C.)
MacDonnell, Hercules H G 2 Kildare-place, Dublin.
*McEwan, John. 9 Melville-terrace, Stirling, N.B
1859. ‡Macfarlane, Alexander. 73 Bon Accord-street, Aberdeen.
1871. §M'Farlane, Donald. The College Laboratory, Glasgow.
1855. *Macfarlane, Walter. 22 Park-circus, Glasgow
1854. *Macfie, Robert Andrew. 13 Victoria-street, Westminster, S W.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1855. ‡MacGeorge, Andrew, jun. 21 St, Vincent-place, Glasgow
1872. ‡M'George, Mungo. Nithodale, Laurie-park, Sydenham, S E
1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire
1855. ‡M'Gregor, Alexander Bennett. 19 Woodside-crescent, Glasgow.
1855. ‡MacGregor, James Watt. 2 Laurence-place, Partick, Glasgow.
1876. §M'Grigor, Alexander B. 19 Woodside-terrace, Glasgow.
1859. ‡M'Hardy, David. 54 Netherkinkgate, Aberdeen
1874. ‡MacIlwaine, Rev. William, D.D., M.R I.A. Ulsterville, Belfast.
1876. §Macindoe, Patrick. 9 Somerset-place, Glasgow.
1859. ‡Macintosh, John. Middlefield House, Woodside, Aberdeen.

Year of Election

1867. *M'INTOSH, W. C., M.D., F.L.S. Murthly, Perthshire.
1854. *MacIver, Charles. 8 Abercromby-square, Liverpool.
1871. ‡Mackay, Rev. A., LL.D., F.R.G.S. 2 Hatton-place, Grange, Edinburgh.
1873. ‡MCKENDRICK, JOHN G., M.D., F.R.S.E. 2 Chester-street, Edinburgh.
1865. ‡Mackeson, Henry B., F.G.S. Hythe, Kent.
1872. *Mackey, J. A. 24 Buckingham-place, Brighton.
1867. §MACKIE, SAMUEL JOSEPH, F.G.S. 84 Kensington Park-road, London, W.
*Mackinlay, David. Great Western-terrace, Hillhead, Glasgow.
1865. †Mackintosh, Daniel, F.G.S. 36 Derby-road, Higher Tranmere, Birkenhead.
1850. ‡Macknight, Alexander. 12 London-street, Edinburgh.
1867. ‡Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *MCLACHLAN, ROBERT, F.L.S. 39 James-grove, Lewisham, S.E.
1873. ‡McLandsborough, John, C.E., F.R.A.S., F.G.S. Shipley, near Bradford, Yorkshire.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1864. §MACLAREN, DUNCAN, M.P. Newington House, Edinburgh.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1876. §M'Lean, Charles. 6 Claremont-terrace, Glasgow.
1876. §M'Lean, Mrs. Charles. 6 Claremont-terrace, Glasgow.
1859. ‡MACLEAR, SIR THOMAS, F.R.S., F.R.G.S., F.R.A.S., late Astronomer Royal at the Cape of Good Hope. Cape Town, South Africa.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Campden-hill-road, London, W.
1868. §M'LEOD, HERBERT, F.C.S. Indian Civil Engineering College, Cooper's Hill, Egham.
1875. ‡Macliver, D. 1 Broad-street, Bristol.
1875. ‡Macliver, P. S. 1 Broad-street, Bristol.
1861. *Maclure, John William. 2 Bond-street, Manchester.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey, S.W.
1874. §MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1871. ‡M'Nab, William Ramsay, M.D., Professor of Botany in the Royal College of Science, Dublin. 4 Vernon-parade, Clontarf, Dublin.
1870. ‡Macnaught, John, M.D. 74 Huskisson-street, Liverpool.
1867. §M'Neill, John. Balhousie House, Perth.
MACNEILL, The Right Hon. Sir JOHN, G.C.B., F.R.S.E., F.R.G.S. Granton House, Edinburgh.
MACNEILL, Sir JOHN, LL.D., F.R.S., M.R.I.A. 17 The Grove, South Kensington, London, S.W.
1859. ‡*Macpherson, Rev. W. Kilmuir Easter, Scotland.*
1852. *Macrory, Adam John. Duncairn, Belfast.
*MACRORY, EDMUND, M.A. 40 Leinster-square, Bayswater, London, W.
1876. §Mactear, James. 16 Burnbank-gardens, Glasgow.
1855. ‡M'Tyre, William, M.D. Maybole, Ayrshire.
1855. ‡MACVICAR, Rev. JOHN GIBSON, D.D., LL.D. Moffat, N.B.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Philip. 2 Portsdown-road, London, W.
Magor, J. B. Redruth, Cornwall.
1860. §MAIN, Rev. R., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1869. ‡*Main, Robert. Admiralty, Somerset House, W.C.*
1866. §MAJOR, RICHARD HENRY, F.S.A., F.R.G.S. British Museum, London, W.C.
*MALAHIDE, The Right Hon. Lord TALBOT DE, M.A., F.R.S., F.G.S., F.S.A. Malahide Castle, Co. Dublin.

Year of
Election

*Malcolm, Frederick. Morden College, Blackheath, London, S.E.
1870. *Malcolm, Sir James, Bart. The Priory, St. Michael's Hamlet, Aigburth, Liverpool.
1874. §Malcolmson, A. B. Friends' Institute, Belfast.
1863. ‡Maling, C. T. Lovaine-crescent, Newcastle-on-Tyne.
1857. ‡Mallet, John William, Ph.D., F.C.S., Professor of Chemistry in the University of Virginia, U.S.
*MALLET, ROBERT, Ph.D., F.R.S., F.G.S., M.R.I.A. Enmore, The Grove, Clapham-road, Clapham; and 7 Westminster-chambers, Victoria-street, London, S.W.
1876. §Malloch, C. 7 Blythwood-square, Glasgow.
1846. ‡MANBY, CHARLES, F.R.S., F.G.S. 60 Westbourne-terrace, Hyde Park, London, W.
1870. ‡Manifold, W. H. 45 Rodney-street, Liverpool.
1866. §MANN, ROBERT JAMES, M.D., F.R.A.S. 5 Kingsdown-villas, Wandsworth Common, S.W.
Manning, His Eminence Cardinal. 8 York-place, Portman-square, London, W.
1866. ‡Manning, John. Waverley-street, Nottingham.
1864. ‡Mansel, J. C. Long Thorns, Blandford.
1870. ‡Marcoartu, Senor Don Arturo de. Madrid.
1864. ‡MARKHAM, CLEMENTS R., C.B., F.R.S., F.L.S., F.R.G.S., F.S.A. 21 Eccleston-square, Pimlico, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
*Marling, Samuel S., M.P. Stanley Park, Stroud, Gloucestershire.
1871. §MARRECO, A. FREIRE-. College of Physical Science, Newcastle-on-Tyne.
Marriott, John
1857. §Marriott, William, F.C.S. Grafton-street, Huddersfield.
1842. Marsden, Richard. Norfolk-street, Manchester.
1870. ‡Marsh, John. Rann Lea, Rainhill, Liverpool.
1865. ‡Marsh, J. F. Hardwick House, Chepstow.
1856. ‡*Marsh, M. H.*
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1852. ‡Marshall, James D. Holywood, Belfast.
1876. §Marshall, Peter. 6 Parkgrove-terrace, Glasgow.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
1849. *Marshall, William P. 6 Portland-road, Edgbaston, Birmingham.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1871. ‡Martin, Rev. Hugh, M.A. Greenhill Cottage, Lasswade by Edinburgh.
1870. ‡Martin, Robert, M.D. 120 Upper Brook-street, Manchester.
1836. Martin, Studley. 177 Bedford-street South, Liverpool.
1867. *Martin, William, jun. 3 Airlie-place, Dundee.
*Martindale, Nicholas. Berryarbor, Ilfracombe.
*Martineau, Rev. James, LL.D., D.D. 5 Gordon-street, Gordon-square, London, W.C.
1865. ‡Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1875. ‡Martyn, Samuel, M.D. 8 Buckingham-villas, Clifton, Bristol.
1847. ‡MASKELYNE, NEVIL STORY, M.A., F.R.S., F.G.S., Keeper of the Mineralogical Department, British Museum; and Professor of Mineralogy in the University of Oxford. 112 Gloucester-terrace, Hyde-park-gardens, London, W.
1861. *Mason, Hugh. Groby Lodge, Ashton-under-Lyne.
1868. ‡Mason, James Wood, F.G.S. The Indian Museum, Calcutta. (Care of Messrs. Henry S. King & Co., 65 Cornhill, London, E.C.)

Year of Election

1876. §Mason, Robert. Glasgow.
1876. §Mason, Stephen. 9 Rosslyn-terrace, Hillhead, Glasgow.
Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
1870. ‡*Massey, Thomas. 5 Gray's-Inn-square, London, W.C.*
1870. ‡Massy, Frederick. 50 Grove-street, Liverpool.
1876. §Matheson, John. Eastfield, Rutherglen, Glasgow.
1865. *Mathews, G. S. Portland-road, Edgbaston, Birmingham.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 49 Harborne-road, Birmingham.
1876. *Mathiesen, John, jun. Cordale, Renton, Glasgow.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1860. §Matthews, Rev. Richard Brown. Shalford Vicarage, near Guildford.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall Hall, Broseley, Shropshire.
1876. §Maxton, John. 6 Belgrave-terrace, Glasgow.
1864. *Maxwell, Francis. Dunragit, Wigtownshire.
*MAXWELL, JAMES CLERK, M.A., LL.D., F.R.S. L. & E., Professor of Experimental Physics in the University of Cambridge. Glenlair, Dalbeattie, N.B., and 11 Scroope-terrace, Cambridge.
*Maxwell, Robert Perceval. Groomsport House, Belfast.
1865. *May, Walter. Elmley Lodge, Harborne, Birmingham.
1868. ‡Mayall, J. E., F.C.S. Stork's-nest, Lancing, Sussex.
1863. §Mease, George D. Bylton Villa, South Shields.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1867. ‡MELDRUM, CHARLES, M.A., F.R.S. Port Louis, Mauritius.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. St. Thomas's Rectory, Brampton, Chesterfield.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1862. §MENNELL, HENRY J. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1868. §MERRIFIELD, CHARLES W., F.R.S. 20 Girdler's-road, Brook Green, London, W.
1872. ‡Merryweather, Richard M. Clapham House, Clapham Common, London, S.W.
1871. ‡Merson, John. Northumberland County Asylum, Morpeth.
1872. *Messent, John. 429 Strand, London, W.C.
[illegible]

1865. ‡Michie, Alexander. 26 Austin Friars, London, E.C.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1876. *Middleton, Robert T. 197 West George-street, Glasgow.
[illegible] ne, Lancashire.
olne, Lancashire.
Lisburn, Ireland.
1863. ‡Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road, London, E.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1876. §Millar, William. Highfield House, Dennistoun, Glasgow.
1876. §Millar, W. J. 145 Hill-street, Garnethill, Glasgow.
1876. §Miller, Daniel. 258 St. George's-road, Glasgow.
1875. ‡Miller, George. Brentry, near Bristol.

Year of Election.

1865. ‡Miller, Rev. Canon J. C, D D. The Vicarage, Greenwich, S.E

1861. *Miller, Robert. Broomfield House, Reddish, near Manchester

1876. *Miller, Robert. 1 Lily Bank-terrace, Hillhead, Glasgow

1876. §Miller, Thomas Paterson. Morriston House, Cambuslang, N B.

MILLER, WILLIAM HALLOWS, M A, LL D, F R S, F G S, Professor of Mineralogy in the University of Cambridge 7 Scroope-terrace, Cambridge.

1868. *Milligan, Joseph, F L S, F G S, F.R.A S, F R G.S. 6 Craven-street, Strand, London, W C.

1842 Milligan, Robert Acacia in Rawdon, Leeds

1868. §MILLS, EDMUND J, D Sc, F R S, F C S, Young Professor of Technical Chemistry in Anderson's University, Glasgow 234 East George-street, Glasgow.

*Mills, John Robert. 11 Bootham, York

Milne, Admiral Sir Alexander, G.C B, F R.S E 65 Rutland-gate, London, S W

1867. ‡Milne, James. Murie House, Errol, by Dundee

1867. *MILNE-HOME, DAVID, M A., F R S E, F G S. 10 York-place, Edinburgh

1864. *MILTON, The Right Hon Lord, F R G S 17 Grosvenor-street, London, W, and Wentworth, Yorkshire

1865. ‡Minton, Samuel, F G.S Oakham House, near Dudley.

1855. ‡Mirrlees, James Buchanan 45 Scotland-street, Glasgow.

1859. ‡Mitchell, Alexander, M D. Old Rain, Aberdeen

1876. §Mitchell, Andrew. 20 Woodside-place, Glasgow.

1863 ‡Mitchell, C. Walker Newcastle-on-Tyne

1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.

1870 §Mitchell, John York House, Clitheroe, Lancashire.

1868. §Mitchell, John, jun Pole Park House, Dundee

1862. **Mitchell, William Stephen, LL B, F L S, F.G S. Caius College, Cambridge.*

1855. *Moffat, John, C E Ardrossan, Scotland.

1854. §MOFFAT, THOMAS, M D, F.G S, F.R A.S, F.M.S Hawarden, Chester

1864. ‡Mogg, John Rees. High Littleton House, near Bristol.

1866. §MOGGRIDGE, MATTHEW, F G.S. 8 Bina-gardens, South Kensington, London, S W.

1855. §Moir, James 174 Gallogate, Glasgow.

1861. ‡Molesworth, Rev W N, M A. Spotland, Rochdale.

Mollan, John, M.D 8 Fitzwilliam-square North, Dublin.

1852. ‡Molony, William, LL.D. Carrickfergus.

1865. §MOLYNEUX, WILLIAM, F G S. Branston Cottage, Burton-upon-Trent.

1860. ‡Monk, Rev. William, M A, F.R A.S. Wymington Rectory, Higham Ferrers, Northamptonshire.

1853. ‡Monroe, Henry, M D. 10 North-street, Sculcoates, Hull.

1875. §Montgomerie, Major Thomas George, R.E, F R S, F R.G S, Deputy Superintendent of the Great Trigonometrical Survey of India. Athenæum Club, London, S W.

1872. §Montgomery, R. Mortimer. 3 Porchester-place, Edgeware-road, London, W.

1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.

1859. ‡MOORE, CHARLES, F.G.S. 6 Cambridge-terrace, Bath.

1874. §Moore, David, F.L.S. Glasnevin, Dublin.

1857. ‡Moore, Rev. John, D.D. Clontarf, Dublin.

Moore, John. 2 Meridian-place, Clifton, Bristol.

Year of Election

*MOORE, JOHN CARRICK, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W., and Corswall, Wigtonshire.

1866. *MOORE, THOMAS, F.L.S. Botanic Gardens, Chelsea, London, S.W.

1854. ‡MOORE, THOMAS JOHN, Cor. M.Z.S. Free Public Museum, Liverpool.

1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.

1871. ‡MORE, ALEXANDER, F.L.S., M.R.I.A. 3 Botanic View, Glasnevin, Dublin.

1873. §Morgan, Edward Delmar. 15 Rowland-gardens, London, W.

1868. ‡*Morgan, Thomas H. Oakhurst, Hastings.*

1833. Morgan, William, D.C.L. Oxon. Uckfield, Sussex.

1867. ‡Morison, William R. Dundee.

1863. ‡MORLEY, SAMUEL, M.P. 18 Wood-street, Cheapside, London, E.C.

1865. *Morrieson, Colonel Robert. Oriental Club, Hanover-square, London, W.

*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.

Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.

1870. §Morris, Rev. S. S. O. The Grammar School, Dolgelly.

1874. ‡Morrison, G. J., C.E. 5 Victoria-street, Westminster, S.W.

1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.

1863. ‡*Morrow, R. J. Bentick-villas, Newcastle-on-Tyne.*

1865. §Mortimer, J. R. St. John's-villas, Driffield.

1869. ‡Mortimer, William. Bedford-circus, Exeter.

1857. §MORTON, GEORGE H., F.G.S. 21 West Derby-street, Liverpool.

1858. *MORTON, HENRY JOSEPH. Garforth House, West Garforth, near Leeds.

1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.

1857. ‡Moses, Marcus. 4 Westmoreland-street, Dublin.

Mosley, Sir Oswald, Bart., D.C.L. Rolleston Hall, Burton-upon-Trent, Staffordshire.

Moss, John. Otterspool, near Liverpool.

1870. ‡Moss, John Miles, M.A. 2 Esplanade, Waterloo, Liverpool.

1873. *Mosse, George Staley. Cowley Hall, near Uxbridge.

1864. *Mosse, J. R. Public Works' Department, Ceylon. (Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.)

1873. ‡Mossman, William. Woodhall, Calverley, Leeds.

1869. §MOTT, ALBERT J. Adsett Court, Westbury-on-Severn.

1865. §Mott, Charles Grey. The Park, Birkenhead.

1866. §Mott, Frederick T., F.R.G.S. 1 De Montfort-street, Leicester.

1872. ‡Mott, Miss Minnie. 1 De Montfort-street, Leicester.

1862. *MOUAT, FREDERICK JOHN, M.D., Local Government Inspector. 12 Durham-villas, Campden Hill, London, W.

1856. ‡Mould, Rev. J. G., B.D. Fulmodeston Rectory, Dereham, Norfolk.

1863. ‡Mounsey, Edward. Sunderland.

Mounsey, John. Sunderland.

1861. *Mountcastle, William Robert. Bridge Farm, Ellenbrook, near Manchester.

Mowbray, James. Combus, Clackmannan, Scotland.

1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.

1874. §Muir, M. M. Pattison, F.R.S.E. Owens College, Manchester.

1876. *Muir, John. 6 Park-gardens, Glasgow.

1876. §Muir, Thomas. High School, Glasgow.

1871. ‡*Muir, W. Hamilton.*

1872. ‡Muirhead, Alexander, D.Sc., F.C.S. 159 Camden-road, London, N.

1871. *Muirhead, Henry, M.D. Bushy Hill, Cambuslang, Lanarkshire.

Year of Election.

1876. §Muirhead, R. F. Meikle Cloak, Lochwinnoch, Renfrewshire.
1857. ‡*Mullins, M. Bernard, M.A., C.E.*
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡MUNDELLA, A. J., M.P., F.R.G.S. The Park, Nottingham.
1876. §Munro, Donald, F.C.S. 97 Eglinton-street, Glasgow.
1864. *MUNRO, Major-General WILLIAM, C.B., F.L.S. United Service Club, Pall Mall, London, S.W.; and Mapperton Lodge, Farnborough, Hants.
1872. *Munster, H. Sillwood Lodge, Brighton.
1872. *Munster, William Felix. 41 Brompton-square, London, W.
1864. §MURCH, JEROM. Cranwells, Bath.
*Murchison, John Henry. Surbiton Hill, Kingston.
1864. *Murchison, K. R. Ashurst Lodge, East Grinstead.
1876. §Murdoch, James. Altony Albany, Girvan, N.B.
1855. ‡Murdoch, James B. Hamilton-place, Langside, Glasgow.
1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1860. ‡Murray, Adam. 4 Westbourne-crescent, Hyde Park, London, W.
1850. ‡MURRAY, ANDREW, F.L.S. 67 Bedford-gardens, Kensington, London, W.
1871. ‡Murray, Dr. Ivor, F.R.S.E. The Knowle, Brenchley, Staplehurst, Kent.
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1871. §Murray, John. 3 Clarendon-crescent, Edinburgh.
1859. ‡Murray, John, M.D. Forres, Scotland.
*Murray, John, C.E. Downlands, Sutton, Surrey.
‡Murray, Rev. John. Morton, near Thornhill, Dumfriesshire.
1872. ‡Murray, J. Jardine. 99 Montpellier-road, Brighton.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
1859. *Murton, James. Highfield, Silverdale, Carnforth, Lancaster.
Musgrave, The Venerable Charles, D.D., Archdeacon of Craven, Halifax.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1865. ‡Myers, Rev. E., F.G.S. 3 Waterloo-road, Wolverhampton.
1859. §MYLNE, ROBERT WILLIAM, F.R.S., F.G.S., F.S.A. 21 Whitehall-place, London, S.W.

1850. ‡Nachot, H. W., Ph.D. 73 Queen-street, Edinburgh.
1842. Nadin, Joseph. Manchester.
1855. *NAPIER, JAMES R., F.R.S. 22 Blythwood-square, Glasgow.
1876. §Napier, James S. 9 Woodside-place, Glasgow.
1876. §Napier, John. Saughfield House, Hillhead, Glasgow.
*Napier, Captain Johnstone, C.E. Laverstock House, Salisbury.
1839. *NAPIER, The Right Hon. Sir JOSEPH, Bart. 4 Merrion-square South, Dublin.
Napper, James William L. Loughcrew, Oldcastle, Co. Meath.
1872. §Nares, Captain Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. Stoneham House, Christchurch-road, Winchester.
1866. ‡Nash, Davyd W., F.S.A., F.L.S. 10 Imperial-square, Cheltenham.
1850. *NASMYTH, JAMES. Penshurst, Tunbridge.
1864. ‡Natal, John William Colenso, D.D., Lord Bishop of. Natal.
1860. ‡Neate, Charles, M.A. Oriel College, Oxford.
1873. ‡Neill, Alexander Renton. Fieldhead House, Bradford, Yorkshire.
1873. ‡Neill, Archibald. Fieldhead House, Bradford, Yorkshire.

Year of
Election

1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1865 ‡Neilson, W. Montgomerie. Glasgow.
1876. §Nelson, D M 48 Gordon-street, Glasgow.
Ness, John. Helmsley, near York.
1868 ‡Nevill, Rev H R The Close, Norwich
1866. *Nevill, Rev Samuel Tarratt, D.D, F.L S., Bishop of Dunedin, New Zealand
1857 ‡Neville, John, C E, M R I A. Roden-place, Dundalk, Ireland.
1852. ‡Neville, Parke, C E 58 Pembroke-road, Dublin.
1869. ‡Nevins, John Birkbeck, M D. 3 Abercromby-square, Liverpool.
1842. New, Herbert Evesham, Worcestershire
Newall, Henry. Hare Hill, Littleborough, Lancashire.
*Newall, Robert Stirling, F R S., F.R A S. Ferndene, Gateshead-upon-Tyne.
1860 *Newdigate, Albert L 2 The Pavement, Clapham Common, London, S W.
1876 §Newhaus, Albert 1 Prince's-terrace, Glasgow.
1842 *NEWMAN, Professor FRANCIS WILLIAM 15 Arundel-crescent, Weston-super-Mare
1863 *NEWMARCH, WILLIAM, F R.S. Beech Holme, Clapham Common, London, S.W.
1866 **Newmarch, William Thomas*
1877. §Newth, A H, M D Hayward's Heath, Sussex
1860. *NEWTON, ALFRED, M A, F R S, F.L S, Professor of Zoology and Comparative Anatomy in the University of Cambridge Magdalen College, Cambridge
1872 ‡Newton, Rev. J 125 Eastern-road, Brighton.
1865. ‡Newton, Thomas Henry Goodwin Clopton House, near Stratford-on-Avon.
1867. ‡Nicholl, Thomas, ex-Dean of Guild Dundee.
1875. ‡Nicholls, J F. City Library, Bristol.
1874. §Nicholls, H. F. King's-square, Bridgewater, Somerset.
1866. †NICHOLSON, SIR CHARLES, Bart, D C.L, LL D, M D, F.G.S, F.R G.S 26 Devonshire-place, Portland-place, London, W.
1838. *Nicholson, Cornelius, F G.S, F.S A. Wellfield, Muswell Hill, London, N.
1861 *Nicholson, Edward. 88 Mosley-street, Manchester.
1871. §Nicholson, E Chambers Herne-hill, London, S.E.
1867. ‡NICHOLSON, HENRY ALLEYNE, M D, D Sc., F G S., Professor of Natural History in the University of St. Andrews, N B.
1850. ‡NICOL, JAMES, F R S.E, F G.S, Professor of Natural History in Marischal College, Aberdeen.
1867. ‡Nimmo, Dr Matthew, L.R C.S.E. Nethergate, Dundee.
1877. *Niven, James, M.A. Queen's College, Cambridge
Niven, Ninian. Clonturk Lodge, Drumcondra, Dublin.
‡Nixon, Randal, C. J, M A. Green Island, Belfast.
1864. ‡NOAD, HENRY M, Ph.D, F R S, F.C.S. St. George's Hospital, London, S.W.
1868. *NOBLE, Captain, F R.S. Elswick Works, Newcastle-on-Tyne.
1870. ‡Nolan, Joseph. 14 Hume-street, Dublin
1860. *Nolloth, Rear-Admiral Matthew S., R.N., F.R.G.S. United Service Club, S.W.; and 13 North-terrace, Camberwell, London, S.E.
1859. ‡Norfolk, Richard. Messrs. W. Rutherford and Co., 14 Canada Dock, Liverpool.
1868. ‡Norgate, William. Newmarket-road, Norwich.
1863. §NORMAN, Rev. ALFRED MERLE, M.A. Burnmoor Rectory, Fence House, Co. Durham.

Year of Election

Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. §Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1866. ‡North, Thomas. Cinder-hill, Nottingham.
1869. ‡NORTHCOTE, The Right Hon. Sir STAFFORD H., Bart., C.B., M.P., F.R.S. Pynes, Exeter.
*NORTHWICK, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of. Norwich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.

O'Callaghan, George. Tallas, Co. Clare.
Odgers, Rev. William James. Savile House, Weston-road, Bath.
1858. *ODLING, WILLIAM, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. The Museum, Oxford.
1857. ‡O'Donnavan, William John. Portarlington, Ireland.
1870. ‡O'Donnell, J. O., M.D. 34 Rodney-street, Liverpool.
1866. ‡Ogden, James. Woodhouse, Loughborough.
1876. §Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1859. ‡Ogilvie, C. W. Norman. Baldovan House, Dundee.
*OGILVIE-FORBES, GEORGE, M.D., Professor of the Institutes of Medicine in Marischal College, Aberdeen. Boyndlie, Fraserburgh, N.B.
1874. §Ogilvie, Thomas Robertson. 19 Brisbane-street, Greenock, N.B.
1863. ‡Ogilvy, G. R. Inverquharity, N.B.
1863. ‡OGILVY, Sir JOHN, Bart. Inverquharity, N.B.
*Ogle, William, M.D., M.A. The Elms, Derby.
1859. ‡Ogston, Francis, M.D. 18 Adelphi-court, Aberdeen.
1837. ‡O'Hagan, John. 22 Upper Fitzwilliam-street, Dublin.
1874. §O'HAGAN, The Right Hon. Lord. Dublin.
1862. ‡O'KELLY, JOSEPH, M.A. 51 Stephen's-green, Dublin.
1857. ‡O'Kelly, Matthias J. Dalkey, Ireland.
1853. §OLDHAM, JAMES, C.E. Cottingham, near Hull.
1857. *OLDHAM, THOMAS, M.A., LL.D., F.R.S., F.G.S., M.R.I.A., Director of the Geological Survey of India. 1 Hastings-street, Calcutta.
1860. ‡*O'Leary, Professor Purcell, M.A. Queenstown.*
1863. ‡Oliver, Daniel, F.R.S., Professor of Botany in University College, London. Royal Gardens, Kew, W.
1874. ‡O'Meara, Rev. Eugene. Newcastle Rectory, Hazlehatch, Ireland.
*OMMANNEY, Vice-Admiral ERASMUS, C.B., F.R.S., F.R.A.S., F.R.G.S. 6 Talbot-square, Hyde Park, London, W.; and United Service Club, Pall Mall, London, S.W.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1842. ORMEROD, GEORGE WAREING, M.A., F.G.S. Brookbank, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham-hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1876. §Orr, John B. Granville-terrace, Crosshill, Glasgow.
1835. ORPEN, JOHN H., LL.D., M.R.I.A. 58 Stephen's-green, Dublin.
1873. ‡Osborn, George. 47 Kingcross-street, Halifax.
1865. ‡Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.

Year of
Election.

*OSLER, A. FOLLETT, F R S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. 50 Carpenter-road, Edgbaston, Birmingham
1860. *Osler, Sidney F. 1 Pownall-gardens, Hounslow, near London
1854. ‡Outram, Thomas. Greetland, near Halifax
OVERSTONE, SAMUEL JONES LLOYD, Lord, F G.S. 2 Carlton-gardens, London, S.W , and Wickham Park, Bromley.
1870. ‡Owen, Harold The Brook Villa, Liverpool
1857. ‡Owen, James H. Park House, Sandymount, Co. Dublin
OWEN, RICHARD, C B , M D , D C L., LL D , F R S , F L S., F G S , Hon M R S E , Director of the Natural-History Department, British Museum. Sheen Lodge, Mortlake, Surrey, S.W.

1859. ‡PAGE, DAVID, LL D , F R S E , F G S College of Physical Science, Newcastle-upon-Tyne
1872 *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.
1875. ‡Paine, William Henry, M D , F G S Stroud, Gloucestershire
1870. *Palgrave, R. H Inglis 11 Britannia-terrace, Great Yarmouth.
1873 ‡Palmer, George The Acacias, Reading, Berks.
1866. §Palmer, H 76 Goldsmith-street, Nottingham.
1866. §Palmer, William. Iron Foundry, Canal-street, Nottingham.
1872. *Palmer, W. R 376 Coldharbour-lane, Stockwell, S.W.
Palmes, Rev. William Lindsay, M A. The Vicarage, Hornsea, Hull.
1857. *Parker, Alexander, M R I A 59 William-street, Dublin.
1863. ‡Parker, Henry Low Elswick, Newcastle-on-Tyne.
1863. ‡Parker, Rev Henry Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.
1874 ‡Parker, Henry R , LL D. Methodist College, Belfast.
Parker, Joseph, F G.S. Upton Chaney, Bitton, near Bristol.
Parker, Richard Dunscombe, Cork.
1865. *Parker, Walter Mantel. High-street, Alton, Hants
Parker, Rev William Saham, Norfolk.
1853 ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling. King's Norton, near Birmingham.
1864 §PARKES, WILLIAM. 23 Abingdon-street, Westminster, S W.
1859. ‡Parkinson, Robert, Ph.D. West View, Toller-lane, Bradford, Yorkshire
1862. *Parnell, John, M A Hadham House, Upper Clapton, London, E.
Parnell, Richard, M D , F.R.S E Gattonside Villa, Melrose, N.B
1865. *Parsons, Charles Thomas. 8 Portland-road, Edgbaston, Birmingham.
1875. ‡Pass, Alfred C. 16 Redland Park, Clifton, Bristol.
1855. ‡Paterson, William. 100 Brunswick-street, Glasgow
1861. ‡Patterson, Andrew Deaf and Dumb School, Old Trafford, Manchester.
1871. *Patterson, A Henry. 3 Old-buildings, Lincoln's-Inn, London, W.C.
1863. ‡Patterson, H L. Scott's House, near Newcastle-on-Tyne.
1867. ‡Patterson, James. Kinnettles, Dundee.
1871. ‡*Patterson, John.*
1876 §Patterson, T L Belmont, Margaret-street, Greenock.
1874 ‡Patterson, W. H , M.R I A. 26 High-street, Belfast.
1863 ‡Pattinson, John. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William Felling, near Newcastle-on-Tyne.
1867. §Pattison, Samuel R., F.G.S. 50 Lombard-street, London, E.C.
1864. ‡Pattison, Dr T. H. London-street, Edinburgh.
1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S., Lecturer on Physiology and Comparative Anatomy and Zoology at Guy's Hospital. 35 Grosvenor-street, London, W.
1864. ‡Payne, Edward Turner. 3 Sydney-place, Bath.

Year of Election.
1851 ‡Payne, Joseph. 4 Kildare-gardens, Bayswater, London, W.
1866. ‡Payne, Dr Joseph F. 4 Kildare-gardens, Bayswater, London, W.
1876. §Peace, G. H. Beech House, Eccles, near Manchester
1847. ‡PEACH, CHARLES W., Pres. R P.S. Edin , A.L S 30 Haddington-place, Leith-walk, Edinburgh.
1863. §Peacock, Richard Atkinson, C E., F G S 2 Moselle-villas, St Peter's-road, Margate
1875. §Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C
1876. §Pearce, W Elmpark House, Govan, Glasgow
*Pearsall, Thomas John, F C S Birkbeck Literary and Scientific Institution, Southampton-buildings, Chancery-lane, London, W C.
1875. §Pearson, H W Tramore Villa, Nugent Hill, Cotham, Bristol.
1872 *Pearson, Joseph. Lenn Side Works, Nottingham
1870 ‡Pearson, Rev. Samuel. 48 Prince's-road, Liverpool
1863. §Pease, H F Brinkburn, Darlington
1863. *Pease, Joseph W , M P Hutton Hall, near Guisborough.
1863. ‡Pease, J W. Newcastle-on-Tyne
1858. *Pease, Thomas, F G S Cote Bank, Westbury-on-Trym, near Bristol.
Peckitt, Henry Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F L S , F R G S. Harecroft House, Wisbeach, Cambridgeshire
*Peckover, Algernon, F.L S. Sibaldsholme, Wisbeach, Cambridgeshire
*Peckover, William, F S A Wisbeach, Cambridgeshire
*Peel, George Soho Iron Works, Manchester
1873. §Peel, Thomas 9 Hampton-place, Bradford, Yorkshire
1861. *Peile, George, jun. Shotley Bridge, Co Durham
1861 *Peiser, John Barnfield House, 491 Oxford-street, Manchester.
1865 ‡Pemberton, Oliver 18 Temple-row, Birmingham.
1861 *Pender, John, M P 18 Arlington-street, London, S.W
1868 ‡Pendergast, Thomas. Lancefield, Cheltenham
1856. §PENGELLY, WILLIAM, F R S , F.G S. Lamorna, Torquay
1875. ‡Percival, Rev. J , M A , LL D. The College, Clifton, Bristol.
1845. ‡PERCY, JOHN, M D , F.R S , F G S , Professor of Metallurgy in the Government School of Mines Museum of Practical Geology, Jermyn-street, S W , and 1 Gloucester-crescent, Hyde Park, London, W.
*Perigal, Frederick. Thatched House Club, St. James's-street, London, S W.
1868. *PERKIN, WILLIAM HENRY, F R S., F C S. The Chestnuts, Sudbury, Harrow.
1861. ‡Perkins, Rev. George. St James's View, Dickenson-road, Rusholme, near Manchester
Perkins, Rev. R B , D C L Wotton-under-Edge, Gloucestershire.
1864. *Perkins, V. R. The Brands, Wotton-under-Edge, Gloucestershire.
1861. ‡*Perring, John Shae.* 104 *King-street, Manchester*
Perry, The Right Rev. Charles, M A., D D. 32 Avenue-road, Regent's Park, London, N.W.
1874. ‡Perry, John. 5 Falls-road, Belfast.
*Perry, Rev. S. G. F., M.A Tottington Vicarage, near Bury.
1870. *PERRY, Rev. S. J., F R S., F.R.A.S., F.M.S. Stonyhurst College Observatory, Whalley, Blackburn.
1861. *Petrie, John. South-street, Rochdale.
Peyton, Abel. Oakhurst, Edgbaston, Birmingham.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 108 Marina, St. Leonard's-on-Sea.

Year of Election.

1867. ‡PHAYRE, Major-General Sir ARTHUR, K C S.I. East India United Service Club, St. James's-square, London, S W.

1863. *PHENÉ, JOHN SAMUEL, LL D , F S A , F G S , F.R G.S. 5 Carlton-terrace, Oakley-street, London, S W

1870 §Philip, T D 51 South Castle-street, Liverpool

1853. *Philips, Rev Edward Hollington, Uttoxeter, Staffordshire.

1853 *Philips, Herbert 35 Church-street, Manchester.

*Philips, Mark Welcombe, Stratford-on-Avon.

Philips, Robert N The Park, Manchester

1863. ‡Philipson, Dr. 1 Saville-row, Newcastle-on-Tyne

1859. *PHILLIPS, Major-General Sir B. TRAVELL. United Service Club, Pall Mall, London, S W.

1862 ‡Phillips, Rev George, D D Queen's College, Cambridge.

1870 ‡PHILLIPS, J ARTHUR. Cressington Park, Aigburth, Liverpool.

1868 ‡Phipson, R. M , F S A. Surrey-street, Norwich

1868 ‡PHIPSON, T L , Ph D 4 The Cedars, Putney, Surrey, S.W.

1864 ‡Pickering, William. Oak View, Clevedon

1861. ‡Pickstone, William Radcliff Bridge, near Manchester

1870. §Picton, J Allanson, F S.A Sandyknowe, Wavertree, Liverpool.

1870. ‡Pigot, Rev E V. Malpas, Cheshire.

1871. ‡Pigot, Thomas F Royal College of Science, Dublin.

*Pike, Ebenezer Besborough, Cork

1865 ‡PIKE, L OWEN 25 Carlton-villas, Maida-vale, London, W

1873. §Pike, W H 4 The Grove, Highgate, London, N

1857. ‡Pilkington, Henry M , M A , Q C 45 Upper Mount-street, Dublin

1863. *PIM, Captain BEDFORD C T , R N , M P , F R.G S. Leaside, Kingswood-road, Upper Norwood, London, S E.

Pim, George, M R I A Brennan's Town, Cabinteely, Dublin.

Pim, Jonathan Harold's Cross, Dublin.

Pim, William H Monkstown, Dublin

1861. ‡*Pincoffs, Simon*

1868 ‡Pinder, T R St. Andrews, Norwich

1876 §Pirie, Rev G Queen's College, Cambridge

1859. ‡Pirrie, William, M D , LL.D 238 Union-street West, Aberdeen.

1866. ‡Pitcairn, David Dudhope House, Dundee.

1875. ‡Pitman, John Redcliff Hill, Bristol.

1864. ‡Pitt, R 5 Widcomb-terrace, Bath

1869. §PLANT, JAMES, F G S 40 West-terrace, West-street, Leicester

1865. ‡Plant, Thomas L Camp-hill, and 33 Union-street, Birmingham.

1867. ‡PLAYFAIR, Lieut -Colonel R. L , H.M. Consul, Algeria. (Messrs. King & Co , Pall Mall, London, S W.)

1842. PLAYFAIR, The Right Hon LYON, C B , Ph D , LL D , M P , F R S L & E , F C.S. 68 Onslow-gardens, South Kensington, London, S.W.

1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.

1861. *POCHIN, HENRY DAVIS, F C S Broughton Old Hall, Manchester.

1846. ‡POLE, WILLIAM, Mus Doc., F R S , M.I C.E. Athenæum Club, Pall Mall, London, S W

*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.

Pollock, A. 52 Upper Sackville-street, Dublin.

1862. *Polwhele, Thomas Roxburgh, M A., F.G.S. Polwhele, Truro, Cornwall.

1854. ‡Poole, Braithwaite. Birkenhead.

1868. ‡*Pooley, Thomas A., B.Sc. South Side, Clapham Common, London, S.W.*

1868. ‡Portal, Wyndham S. Malsanger, Basingstoke.

Year of Election.

*PORTER, HENRY J. KER, M.R.I.A. Hanover Square Club, Hanover-square, London, W.
1874. ‡Porter, Rev. J. Leslie, D.D., LL.D. College Park, Belfast.
1866. §Porter, Robert. Beeston, Nottingham.
Porter, Rev. T. H., D.D. Tullyhogue, Co. Tyrone.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
*POTTER, EDMUND, F.R.S. Camfield-place, Hatfield, Herts.
1842. Potter, Thomas. George-street, Manchester.
1863. ‡Potts, James. 26 Sandhill, Newcastle-on-Tyne.
1857. *POUNDEN, Captain LONSDALE, F.R.G.S. Junior United Service Club, St. James's-square, London, S.W.; and Brownswood House, Enniscorthy, Co. Wexford.
1873. *Powell, Francis S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1857. ‡Power, Sir James, Bart. Edermine, Enniscorthy, Ireland.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuck, Uddingstone, Hamilton, Scotland.
1864. ‡*Prangley, Arthur.*
1869. *Preece, William Henry. Gothic Lodge, Wimbledon Common, London, S.W.
Prest, The Venerable Archdeacon Edward. The College, Durham.
*PRESTWICH, JOSEPH, F.R.S., F.G.S., F.C.S., Professor of Geology in the University of Oxford. 34 Broad-street, Oxford; and Shoreham, near Sevenoaks.
1871. ‡Price, Astley Paston. 47 Lincoln's-Inn-Fields, London, W.C.
1856. *PRICE, Rev. BARTHOLOMEW, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford. 11 St. Giles's-street, Oxford.
1872. ‡Price, David S., Ph.D. 26 Great George-street, Westminster, S.W.
Price, J. T. Neath Abbey, Glamorganshire.
1875. *Price, Rees. 54 Loftus-road, Shepherd's Bush, London, W.
1870. *Price, Captain W. E., M.P., F.G.S. Tibberton Court, Gloucester.
1875. *Price, William Philip. Tibberton Court, Gloucester.
1865. *Prichard, Thomas, M.D. Abington Abbey, Northampton.
1865. ‡*Prideaux, J. Symes.* 209 *Piccadilly, London, W.*
1870. §Priestley, John. Lloyd-street, Greenheys, Manchester.
1875. §Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1835. *Pritchard, Andrew, F.R.S.E. 87 St. Paul's-road, Canonbury, London, N.
1846. *PRITCHARD, Rev. CHARLES, M.A., F.R.S., F.G.S., F.R.A.S., Professor of Astronomy in the University of Oxford. 8 Keble-terrace, Oxford.
1872. ‡Pritchard, Rev. W. Gee. Brignal Rectory, Barnard Castle, Co. Durham.
1876. *Pritchard, Urban, M.D., F.R.C.S. 3 George-street, Hanover-square, London, W.
1871. ‡*Procter, James. Morton House, Clifton, Bristol.*
1863. ‡Procter, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, Thomas. Elmsdale House, Clifton Down, Bristol.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1858. §Proctor, William, M.D., F.C.S. 24 Petergate, York.
1863. *Prosser, Thomas. West Boldon, Newcastle-on-Tyne.
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1865. ‡Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.
1872. *Pryor, M. Robert. Weston Manor, Stevenage, Herts.

Year of
Election

1871. *Puckle, Thomas John. Woodcote-grove, Carshalton, Surrey
1873 ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. ‡Pullar, John. 4 Leonard Bank, Perth.
1867. *Pullar, Robert. 6 Leonard Bank, Perth.
1842 *Pumphrey, Charles. 33 Frederick-road, Edgbaston, Birmingham
Punnett, Rev. John, M.A., F.C.P.S. St Earth, Cornwall.
1869. ‡*Purchas, Rev. W. H.*
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1860. ‡PURDY, FREDERICK, F.S.S., Principal of the Statistical Department of the Poor Law Board, Whitehall, London. Victoria-road, Kensington, London, W.
1874 ‡Purser, Frederick, M.A. Rathmines, Dublin.
1866 ‡Purser, Professor John, M.A., M.R.I.A. Queen's College, Belfast.
1860. *Pusey, S. E. B. Bouverie-. Pusey House, Faringdon.
1868. §PYE-SMITH, P. H., M.D. 56 Harley-street, W.; and Guy's Hospital, London, S.E.
1861. *Pyne, Joseph John. St. German's Villa, St. Lawrence-road, Notting Hill, London, W.

1870 ‡Rabbits, W. T. Forest Hill, London, S.E.
1860. ‡RADCLIFFE, CHARLES BLAND, M.D. 25 Cavendish-square, London, W.
1870 ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
*Radford, William, M.D. Sidmount, Sidmouth.
1861. ‡*Rafferty, Thomas.*
1854. ‡Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.
1870. ‡Raffles, William Winter. Sunnyside, Prince's Park, Liverpool.
1855. ‡Rainey, Harry, M.D. 10 Moore-place, Glasgow.
1864. ‡Rainey, James T. St. George's Lodge, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1863. ‡RAMSAY, ALEXANDER, F.G.S. Kilmorey Lodge, 6 Kent-gardens, Ealing, W.
1845. ‡RAMSAY, ANDREW CROMBIE, LL.D., F.R.S., F.G.S., Director-General of the Geological Survey of the United Kingdom and of the Museum of Economic Geology. Geological Survey Office, Jermyn-street, London, S.W.
1863. ‡*Ramsay, D. R.*
1867. ‡Ramsay, James, jun. Dundee.
1861 ‡Ramsay, John, M.P. Kildalton, Argyleshire
1867. *Ramsay, W. F., M.D. 15 Somerset-street, Portman-square, London, W.
1876. §Ramsay, William, Ph.D. 11 Ashton-terrace, Glasgow.
1873. *Ramsden, William. Bracken Hall, Great Horton, Bradford, Yorkshire.
1835. *Rance, Henry (Solicitor). Cambridge.
1869. *Rance, H. W. Henniker, LL.M. 62 St. Andrew's-street, Cambridge.
1860. ‡Randall, Thomas. Grandepont House, Oxford.
1865. ‡Randel, J. 50 Vittoria-street, Birmingham.
1855. ‡Randolph, Charles. Pollockshiels, Glasgow.
Ranelagh, The Right Hon. Lord. 7 New Burlington-street, Regent-street, London, W.
1868. *Ransom, Edwin, F.R.G.S. Kempstone Mill, Bedford.
1863. §Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡Ransome, Arthur, M.A. Bowdon, Manchester.
Ransome, Thomas. 34 Princess-street, Manchester.
1872. *Ranyard, Arthur Cowper, F.R.A.S. 25 Old-square, Lincoln's-Inn, London, W.C.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.

Year of Election

*RATCLIFF, Colonel CHARLES, F.L.S., F.G.S., F.S.A., F.R.G.S. Wyddrington, Edgbaston, Birmingham.
1864. §Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.
1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.
1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.
1870. §Rathbone, R. R. Beechwood House, Liverpool.
1863. ‡Rattray, W. St. Clement's Chemical Works, Aberdeen.
1874. ‡Ravenstein, E. G., F.R.G.S. 10 Lorn-road, Brixton, London, S.W.
Rawdon, William Frederick, M.D. Bootham, York.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
*Rawlins, John. Shrawley Wood House, near Stourport.
1866. *RAWLINSON, Rev. Canon GEORGE, M.A., Camden Professor of Ancient History in the University of Oxford. The Oaks, Precincts, Canterbury.
1855. *RAWLINSON, Major-General Sir HENRY C., K.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1875. §Rawson, Sir Rawson W., K.C.M.G., C.B. Wombwell House, Gravesend, Kent.
1868. *RAYLEIGH, The Right Hon. Lord, M.A., F.R.S. 4 Carlton-gardens, Pall Mall, London, S.W., and Terling Place, Witham, Essex.
1865. ‡Rayner, Henry. West View, Liverpool-road, Chester.
1870. ‡Rayner, Joseph (Town Clerk). Liverpool.
1852. ‡Read, Thomas, M.D. Donegal-square West, Belfast.
1865. ‡Read, William. Albion House, Epworth, Bawtry.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.
1870. §Reade, Thomas M., C.E., F.G.S. Blundellsands, Liverpool.
1862. *Readwin, Thomas Allison, M.R.I.A., F.G.S. 37 Osborne-road, Tuebrook, Liverpool.
1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1863. ‡Redmayne, R. R. 12 Victoria-terrace, Newcastle-on-Tyne.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. *Ree, H. P. Villa Ditton, Torquay.
1861. ‡REED, EDWARD J., F.R.S., Vice-President of the Institute of Naval Architects. Chorlton-street, Manchester.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1876. §Reid, James. 10 Woodside-terrace, Glasgow.
1869. ‡*Reid, J. Wyatt.*
1874. ‡Reid, Robert, M.A. 35 Dublin-road, Belfast.
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1875. §Reinold, A. W., M.A., Professor of Physical Science. Royal Naval College, Greenwich, S.E.
1866. §RENALS, E. 'Nottingham Express' Office, Nottingham.
1863. ‡Rendel, G. Benwell, Newcastle-on-Tyne.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1869. ‡*Révy, J. J. 16 Great George-street, Westminster, S.W.*
1871. ‡REYNOLDS, JAMES EMERSON, M.A., F.C.S., Professor of Chemistry in the University of Dublin. Royal Dublin Society, Kildare-street, Dublin.
1870. *REYNOLDS, OSBORNE, M.A., Professor of Engineering in Owens College, Manchester. Fallowfield, Manchester.
1858. §Reynolds, Richard, F.C.S. 13 Briggate, Leeds.
Reynolds, William, M.D.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1868. §RICHARDS, Rear-Admiral GEORGE H., C.B., F.R.S., F.R.G.S. The Athenæum Club, London, S.W.

Year of Election

1863. §RICHARDSON, BENJAMIN WARD, M.A., M D., F.R S. 12 Hinde-street, Manchester-square, London, W
1861. §Richardson, Charles 10 Berkeley-square, Bristol
1869. *Richardson, Charles Albert Park, Abingdon, Berks.
1863. *Richardson, Edward. 6 Stanley-terrace, Gosforth, Newcastle-on-Tyne.
1868 *Richardson, George 4 Edward-street, Werneth, Oldham.
1870. ‡Richardson, J H. 3 Arundel-terrace, Cork
1863 ‡*Richardson, John W.*
1870. ‡Richardson, Ralph. 16 Coates-crescent, Edinburgh.
Richardson, Thomas. Montpelier-hill, Dublin.
Richardson, William Micklegate, York.
1861 §Richardson, William. 4 Edward-street, Werneth, Oldham.
1876 §Richardson, William Haden City Glass Works, Glasgow.
1861 ‡*Rickson, Rev. Canon, M A. Shakespeare-street, Ardwick, Manchester.*
1863 ‡Richter, Otto, Ph D. 6 Derby-terrace, Glasgow
1870. ‡Rickards, Dr 30 Upper Parliament-street, Liverpool.
1868 §RICKETTS, CHARLES, M D, F G S 22 Argyle-street, Birkenhead
*RIDDELL, Major-General CHARLES J. BUCHANAN, C B, R A, F.R S. Oaklands, Chudleigh, Devon.
1861 *Riddell, Henry B Whitefield House, Rothbury, Morpeth.
1872 ‡Ridge, James 98 Queen's-road, Brighton
1862 ‡Ridgway, Henry Akroyd, B A Bank Field, Halifax
1861. ‡Ridley, John. 10 Belsize-park, Hampstead, London, N W.
1863 *Rigby, Samuel Bruche Hall, Warrington
1873 ‡Ripley, Edward Acacia, Apperley, near Leeds
1873. §Ripley, H W Acacia, Apperley, near Leeds
*RIPON, The Most Hon the Marquis of, K G, D.C L, F.R S, F.L S. 1 Carlton-gardens, London, S W
1860. ‡Ritchie, George Robert. 4 Watkyn-terrace, Coldharbour-lane, Camberwell, London, S E.
1867. ‡Ritchie, John Flouchar Craig, Dundee.
1855. ‡Ritchie, Robert, C E. 14 Hill-street, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1869. *Rivington, John Great Milton, Tetsworth, Oxon.
1854. ‡Robberds, Rev John, B A. Battledown Tower, Cheltenham.
1860. *ROBBINS, J, F C S 57 Warrington-crescent, Maida-vale, London, W.
Roberton, John. Oxford-road, Manchester.
1859. ‡Roberts, George Christopher. Hull.
1859. ‡Roberts, Henry, F S A. Athenæum Club, London, S W.
1870 *Roberts, Isaac, F G S. 26 Rock Park, Rock Ferry, Cheshire.
1857. ‡Roberts, Michael, M.A. Trinity College, Dublin.
1868 §ROBERTS, W. CHANDLER, F.R S., F G S, F C.S. Royal Mint, London, E.
**Roberts, William P.*
1866. ‡*Robertson, Alister Stuart, M.D., F R G.S. Horwich, Bolton, Lancashire*
1876. §Robertson, Andrew Carrick. Woodend House, Helensburgh, N.B.
1859. ‡Robertson, Dr. Andrew Indego, Aberdeen.
1867. §Robertson, David. Union Grove, Dundee.
1871. ‡Robertson, George, C E., F.R S E. 47 Albany-street, Edinburgh.
1870. *Robertson, John. Bank, High-street, Manchester.
1876. §Robertson, R. A. 9 Queen's-square, Regent Park, Glasgow.
1866. ‡ROBERTSON, WILLIAM TINDAL, M.D. Nottingham.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Tartaragham Glebe, Loughgall, Ireland.

Year of
Election

1859 ‡Robinson, Hardy 156 Union-street, Aberdeen
*Robinson, H Oliver 34 Bishopsgate-street, London, E C
1873 §Robinson, Hugh 3 Donegal-street, Belfast
1866 ‡*Robinson, John*
1861 ‡Robinson, John Atlas Works, Manchester
1863 ‡Robinson, J H Cumberland-row, Newcastle-on-Tyne
1855 ‡*Robinson, M F 116 St Vincent-street, Glasgow*
1875 *Robinson, Robert, C E 2 West-terrace, Darlington
1860 ‡Robinson, Admiral Sir Robert Spencer, K C B, F R S 61 Eaton-place, London, S W
ROBINSON, Rev THOMAS ROMNEY, D D, F R S, F R A S, M R I A, Director of the Armagh Observatory, Armagh
1863 ‡Robinson, T W U Houghton-le-Spring, Durham
1870 ‡Robinson, William 40 Smithdown-road, Liverpool
1870 *Robson, E R 20 Great George-street, Westminster, S W
1876 §Robson, Hazleton R 14 Royal-crescent West, Glasgow
*Robson, Rev John, M A, D D Aymore Lodge, Cathkin-road, Langside, Glasgow
1855 ‡Robson, Neil, C E 127 St Vincent-street, Glasgow
1872 *Robson, William Marchholm, Gillsland-road, Merchiston, Edinburgh
1872 §RODWELL, GEORGE F, F R A S, F C S Marlborough College, Wiltshire
1866 ‡Roe, Thomas Grove-villas, Litchurch
1861 ‡ROFE, JOHN, F G S 9 Crosbie-terrace, Leamington
1860 ‡ROGERS, JAMES E THOROLD, Professor of Economic Science and Statistics in King's College, London Beaumont-street, Oxford
1867 ‡Rogers, James S Rosemill, by Dundee
1869 *Rogers, Nathaniel, M D 87 South-street, Exeter
1870 ‡Rogers, T L, M D Rainhill, Liverpool
1859 ‡ROLLESTON, GEORGE, M A, M D, F R S, F L S Professor of Anatomy and Physiology in the University of Oxford The Park, Oxford
1876 §Rollit, A K, B A, LL D The Literary and Philosophical Society, Hull
1866 ‡Rolph, George Frederick War Office, Horse Guards, London, S W
1876 §Romanes, George John 18 Cornwall-terrace, Regent's Park, London, N W
1863 ‡*Romilly, Edward 14 Hyde Park-terrace, London, W*
1846 ‡Ronalds, Edmund, Ph D Stewartfield, Bonnington, Edinburgh
1860 ‡Roper, C H Magdalen-street, Exeter
1872 *Roper, Freeman Clark Samuel, F L S, F G S Palgrave House, Eastbourne
1855 *ROSCOE, HENRY ENFIELD, B A, Ph D, F R S, F C S, Professor of Chemistry in Owens College, Manchester
1863 ‡Roseby, John Haverholme House, Brigg, Lincolnshire
1874 ‡Ross, Alex Milton, M A, M D, F G S Toronto, Canada
1857 ‡Ross, David, LL D Drumbrain Cottage, Newbliss, Ireland
1872 ‡Ross, James, M D Tenterfield House, Waterfoot, near Manchester
1859 *Ross, Rev James Coulman Baldon Vicarage, Oxford
1861 *Ross, Thomas 7 Wigmore-street, Cavendish-square, London, W
1874 §Ross, Rev William Chapelhill Manse, Rothesay, Scotland
1869 *ROSSE, The Right Hon the Earl of, D C L, F R S, F R A S Birr Castle, Parsonstown, Ireland, and 32 Lowndes-square, London, S W
1865. *Rothera, George Bell 17 Waverley-street, Nottingham

Year of Election.

1876 §Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1861 ‡Routh, Edward J., M.A., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1872 *Row, A. V. Nursing. Observatory, Daba gardens, Vizagapatam, India. (Care of Messrs. King & Co., 45 Pall Mall, London, S.W.)
1861 ‡Rowan, David. Elliot-street, Glasgow.
1876 §Rowan, David. 22 Woodside-place, Glasgow.
1855 ‡*Rowand, Alexander.*
1865 §Rowe, Rev. John. [illegible] Vicarage, Langport, Somerset.
1855 *ROWNEY, THOMAS H., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway. Salerno, Salt Hill, Galway.
*Rowntree, Joseph. 13 Castle gate, York.
1862 ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1876 §Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1861 *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.
1875 ‡Rucker, A. W. Yorkshire College of Science, Leeds.
1869 §Rudler, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.
1856 ‡Rumsey, Henry Wyldbore, M.D., F.R.S., L.R.C.S. Knoll Hill, Prestbury, near Cheltenham.
1873 ‡Rushforth, Joseph. 43 Ash grove, Horton lane, Bradford, Yorkshire.
1847 ‡RUSKIN, JOHN, M.A., F.G.S., Slade Professor of Fine Arts in the University of Oxford. Corpus Christi College, Oxford.
1857 ‡Russell, Rev. C. W., D.D. Maynooth College.
1875 *Russell, The Hon. F. A. R. Pembroke Lodge, Richmond Park, Surrey.
1876 *Russell, George. 103 Blenheim-crescent, Notting Hill, London, W.
1865 ‡Russell, James, M.D. 91 Newhall street, Birmingham.
1859 ‡RUSSELL, The Right Hon. JOHN, Earl, K.G., F.R.S., F.R.G.S. 37 Chesham-place, Belgrave-square, London, S.W.
Russell, John.
RUSSELL, JOHN SCOTT, M.A., F.R.S. L. & E. Sydenham, and 5 Westminster Chambers, London, S.W.
1852 *Russell, Norman Scott. 5 Westminster chambers, London, S.W.
1876 §Russell, R., C.E., F.G.S. 1 Sea View, St. Bees, Carnforth.
1862 §RUSSELL, W. H. L., A.B., F.R.S. 6 The Grove, Highgate, London, N.
1852 *RUSSELL, WILLIAM J., Ph.D., F.R.S., F.C.S., Professor of Chemistry, St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.
1875 §Rutherford, David Greig. Surrey House, Forest Hill, London, S.E.
1871 §RUTHERFORD, WILLIAM, M.D., F.R.S., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1871 ‡*Ruttledge, T. E.*
1875 §Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, London, E.C.
1874 §Rye, E. C., F.Z.S., Librarian R.G.S. 70 Charlewood-road, Putney, S.W.
1865 ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1853 ‡*Rylands, Joseph.*
1861 *RYLANDS, THOMAS GLAZEBROOK, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

*SABINE, General Sir EDWARD, K.C.B., R.A., LL.D., D.C.L., F.R.S., F.R.A.S., F.L.S., F.R.G.S. 13 Ashley-place, Westminster, S.W.
1865 ‡Sabine, Robert. Auckland House, Willesden-lane, London, N.W.

Year of
Election

1871 §Sadler, Samuel Champernowne Purton Court, Purton, near Swindon, Wiltshire
1866 *St Albans, His Grace the Duke of Bestwood Lodge, Arnold, near Nottingham
Salkeld, Joseph Penrith, Cumberland
1857 ‡SALMON, REV GEORGE, D D , D C L , F R S Regius Professor of Divinity in the University of Dublin Trinity College, Dublin.
1873 *Salomons, Sir David, Bart Broomhill, Tunbridge Wells
1872 ‡SALVIN, OSBERT, M A , F R S , F L S Brookland Avenue, Cambridge
1842 Sambrooke, T G 2 Eaton place, London, S W
1861 *Samson Henry 6 St Peter s square, Manchester
1867 ‡Samuelson, Edward Roby, near Liverpool
1870 ‡SAMUELSON, JAMES St Domingo grove, Everton, Liverpool
1861 *Sandeman, Archibald, M A Tulloch, Perth
1876 §Sandeman, David Woodlands, Lenzie, Glasgow
1857 ‡Sanders, Gilbert The Hill, Monkstown, Co Dublin
1872 ‡Sanders, Mrs 8 Powis-square, Brighton
1871 ‡Sanders, William R , M D 11 Walker street Edinburgh
1872 §SANDERSON, J S BURDON, M D , F R S , Professor of Physiology in University College, London 49 Queen Anne-street, London, W
Sandes, Thomas, A B Sallow Glin, Tarbert, Co Kerry
1864 ‡Sandford, William 9 Springfield-place, Bath
1854 ‡Sandon, The Right Hon Lord, M P 39 Gloucester square, London, W.
1873 ‡Sands T C 24 Spring-gardens, Bradford, Yorkshire
1865 ‡Sargant, W L Edmund-street, Birmingham
1868 ‡Saunders, A , C E King s Lynn
1846 ‡Saunders, Trelawney W India Office, London, S W
1864 ‡Saunders, T W , Recorder of Bath 1 Priory-place, Bath
1860 *Saunders, William 3 Gladstone terrace, Brighton
1871 §Savage, W D Ellerslie House, Brighton
1868 ‡Savory, Valentine Cleckheaton near Leeds
1872 §Sawyer, George David 55 Buckingham-place, Brighton
1868 ‡Sawyer, John Robert Grove terrace, Thorpe Hamlet, Norwich
1857 ‡*Scallan, J Joseph*
1850 ‡*Scarth, Pillans 2 James s-place, Leith*
1868 §Schacht, G F 7 Regent s-place, Clifton, Bristol
1842 Schofield, Joseph Stubley Hall, Littleborough, Lancashire
1874 §Scholefield, Henry Windsor-crescent, Newcastle-on-Tyne
*Scholes, T Seddon 10 Warwick-place, Leamington
1876 §Schuman, Sigismond 7 Royal Bank-place, Glasgow
SCHUNCK, EDWARD, F R S , F C S Oaklands Kersall Moor, Manchester
1873 *SCHUSTER, ARTHUR, Ph D Sunnyside, Upper Avenue-road, Regent s Park, London, N W
1861 *Schwabe, Edmund Salis Ryecroft House, Cheetham Hill, Manchester
1847 ‡SCLATER, PHILIP LUTLEY, M A , Ph D , F R S , F L S , Sec Zool Soc (GENERAL SECRETARY) 11 Hanover-square, London, W
1867 ‡SCOTT, ALEXANDER Clydesdale Bank, Dundee
1876 §Scott, Mr Bailie Glasgow
1871 ‡Scott, Rev C G 12 Pilrig-street, Edinburgh
1876 §Scott, D D Glasgow
1859 ‡*Scott, Captain Fitzmaurice Forfar Artillery.*
1872 ‡Scott, Major-General H Y D, C B, R E, F R S. Sunnyside, Ealing, W.

Year of Election

1871 ‡Scott, James S. T. Monkrigg, Haddingtonshire.
1857. *SCOTT, ROBERT H., M.A., F.R.S., F.G.S., F.M.S., Director of the Meteorological Office. 116 Victoria-street, London, S.W.
1861 §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.
1874 ‡Scott, Rev. Robinson, D.D. Methodist College, Belfast.
1864. ‡Scott, Wentworth Lascelles. Wolverhampton.
1858 ‡Scott, William. Holbeck, near Leeds.
1860. §Scott, William Bower. Chudleigh, Devon.
1864 ‡Scott, William Robson, Ph.D. St. Leonards, Exeter.
1859 ‡Seaton, John Love. Hull.
1870 ‡*Seaton, Joseph, M.D.*
1877 §Seaton, Robert Cooper, B.A. Dulwich College, Dulwich, Surrey, S.E.
1861 *SEELEY, HARRY GOVIER, F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geography in King's College, London. 61 Adelaide-road, South Hampstead, London, N.W.
1855 ‡Seligman, H. L. 135 Buchanan-street, Glasgow.
1873 ‡Semple, R. H., M.D. 8 Torrington-square, London, W.C.
1858. *Senior, George, F.S.S. Rosehill Lodge, Dodworth, near Barnsley.
1870 *Sephton, Rev. J. 92 Huskisson-street, Liverpool.
1875 §Seville, Thomas. Elm House, Royton, near Manchester.
1873 §Sewell, Rev. E., M.A., F.G.S., F.R.G.S. Ilkley College, near Leeds.
1868 ‡Sewell, Philip E. Catton, Norwich.
1861 *Seymour, Henry D. 209 Piccadilly, London, W.
Seymour, John. 21 Bootham, York.
1853 ‡Shackles, G. L. 6 Albion-street, Hull.
*Shaen, William. 15 Upper Phillimore-gardens, Kensington, London, W.
1871 *Shand, James. Fullbrooks, Worcester Park, Surrey.
1867 §Shanks, James. Den Iron Works, Arbroath, N.B.
1860 *Shapter, Dr. Lewis, LL.D. The Barnfield, Exeter.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1861. ‡SHARP, SAMUEL, F.G.S., F.S.A. Great Harrowden Hall, near Wellingborough.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
SHARPEY, WILLIAM, M.D., LL.D., F.R.S., F.R.S.E. 50 Torrington-square, London, W.C.
1858. *Shaw, Bentley. Woodfield House, Huddersfield.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865 ‡Shaw, George. Cannon-street, Birmingham.
1870 ‡Shaw, John. 24 Great George-place, Liverpool.
1845 ‡Shaw, John, M.D., F.L.S., F.G.S. Hop House, Boston, Lincolnshire.
1853. ‡Shaw, Norton, M.D. St. Croix, West Indies.
1859. Shepard, John. 41 Drewton-street, Manningham-road, Bradford, Yorkshire.
1863 ‡Shepherd, A. B. 49 Seymour-street, Portman-square, London, W.
1870 §Shepherd, Joseph. 20 Everton-crescent, Liverpool.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1869 ‡*Sherard, Rev. S. H.*
1866 ‡Shilton, Samuel Richard Parr. Sneinton House, Nottingham.
1867. ‡Shinn, William C. Her Majesty's Printing Office, near Fetter-lane, London, E.C.

Year of Election

1870 *SHOOLBRED, JAMES N, C E, F G S Westminster Chambers, London, S W
1875 §Shore, Thomas W, F C S Hartley Institution, Southampton
1861 *Sidebotham, Joseph 19 George-street, Manchester
1872 *Sidebottom, Robert Mersey Bank, Heaton Mersey, Manchester
1873 ‡Sidgwick, R H The Raikes, Skipton
1857 ‡Sidney, Frederick John, LL D, M R I A 19 Herbert-street, Dublin
Sidney, M J F Cowpen, Newcastle-upon-Tyne
1873 *Siemens, Alexander 12 Queen Anne's-gate, Westminster, S W
1856 *SIEMENS, C WILLIAM, D C L, F R S, F C S, M I C E 12 Queen Anne's-gate, Westminster, S W
1859 ‡Sim, John Hardgate, Aberdeen
1871 ‡Sime, James Craigmount House, Grange, Edinburgh
1865 §Simkiss, T M Wolverhampton
1862 ‡Simms, James 138 Fleet-street, London, E C
1874 §Simms, William The Linen Hall, Belfast
1876 §Simon, Frederick 24 Sutherland-gardens, London, W
1847 ‡Simon, John, D C L, F R S, F R C S Medical Officer of the Privy Council 40 Kensington-square, London, W
1866 ‡Simons, George The Park, Nottingham
1871 *SIMPSON, ALEXANDER R, M D, Professor of Midwifery in the University of Edinburgh 52 Queen-street, Edinburgh
1867 ‡Simpson, G B Seafield, Broughty Ferry, by Dundee
1859 ‡Simpson, John Marykirk, Kincardineshire
1863 ‡Simpson, J B, F G S Hedgefield House, Blaydon-on-Tyne
1857 ‡SIMPSON, MAXWELL, M D, F R S, F C S Professor of Chemistry in Queen's College, Cork
1876 §Simpson, Robert 14 Ibrox-terrace, Glasgow
*Simpson, Rev Samuel Greaves House, near Lancaster
Simpson, Thomas Blake-street, York
Simpson, William Bradmore House, Hammersmith, London, W
1859. ‡Sinclair, Alexander 133 George-street, Edinburgh
1876 §Sinclair, James Titwood Bank, Pollokshields, near Glasgow
1874 ‡Sinclair, Thomas Dunedin, Belfast
1834 ‡Sinclair, Vetch, M D 48 Albany-street, Edinburgh
1870 *Sinclair, W P 19 Devonshire-road, Prince's Park, Liverpool
1864 *Sircar, Baboo Mohendro Lall, M D 1344 San Kany, Tollah-street, Calcutta, per Messrs Harrenden & Co 3 Chapel-place, Poultry, London, E C
1865 §Sissons, William 92 Park-street, Hull
1870 §Sladen, Walter Percy, F G S Exley House, near Halifax
1873 ‡Slater, Clayton Barnoldswick, near Leeds
1870 ‡Slater, W B 42 Clifton Park-avenue, Belfast
1842 *Slater, William Park-lane, Higher Broughton, Manchester
1853 ‡*Sleddon, Francis 2 Kingston-terrace, Hull*
1849 §Sloper, George Edgar Devizes
1849 ‡Sloper, Samuel W Devizes
1860 §Sloper, S Elgar Winterton, near Hythe, Southampton
1872 ‡Smale, The Hon Sir John, Chief Justice of Hong Kong
1867 ‡Small, David Gray House, Dundee
1858. ‡Smeeton, G H Commercial-street, Leeds
1876 §Smeiton, James Panmure Villa, Broughty Ferry, Dundee
1867. ‡Smeiton, John G Panmure Villa, Broughty Ferry, Dundee
1867 ‡Smeiton, Thomas A 55 Cowgate, Dundee
1876. §Smellie, Thomas D 213 St. Vincent-street, Glasgow
1857. ‡Smith, Aquila, M D, M R I A 121 Lower Bagot-street, Dublin

Year of Election

1868 ‡Smith, Augustus. Northwood House, Church-road, Upper Norwood, Surrey, S.E.

1872 *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead-heath, London, N.W.

1874 *Smith, Benjamin Leigh. 64 Gower-street, London, W.C.

1873 ‡Smith, C. Sidney College, Cambridge.

1865 ‡SMITH, DAVID, F.R.A.S. 4 Cherry-street, Birmingham.

1866 ‡Smith, Frederick. The Priory, Dudley.

1866 *Smith, F. C., M.P. Bank, Nottingham.

1855 ‡Smith, George. Port Dundas, Glasgow.

1876. §Smith, George. Glasgow.

1855 ‡Smith, George Cruickshank. 19 St. Vincent-place, Glasgow.

1876 *Smith, G. G. 1 2 St. Vincent-street, Glasgow.

*SMITH, HENRY JOHN STEPHEN, M.A., F.R.S., F.C.S., Savilian Professor of Geometry in the University of Oxford, and Keeper of the University Museum. The Museum, Oxford.

1860 *Smith, Heywood, M.A., M.D. 2 Portugal-street, Grosvenor-square, London, W.

1865 ‡*Smith, Isaac.*

1876 §Smith, J. Glasgow.

1870 ‡Smith, James. 140 Bedford-street South, Liverpool.

1873 ‡*Smith, James.*

1871 *Smith, John Alexander, M.D., F.R.S.E. 10 Palmerston-place, Edinburgh.

1874 ‡Smith, John Haigh. Beech Hill, Halifax, Yorkshire.

1867 *Smith, John P., C.E. Haughhead Cottage, Glasgow.

Smith, John Peter George. Sweyney Cliff, near Coalport, Shropshire.

18 2 **Smith, Rev. Joseph Denham.*

1871 ‡Smith, Professor J. William Robertson. Free Church College, Aberdeen.

*Smith, Philip, B.A. 26 South Hill Park, Hampstead, London, N.W.

1860 *Smith, Protheroe, M.D. 42 Park-street, Grosvenor-square, London, W.

1837 Smith, Richard Bryan. Villa Nova, Shrewsbury.

1847 §SMITH, ROBERT ANGUS, Ph.D., F.R.S., F.C.S. 22 Devonshire-street, Manchester.

*Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.

1870 ‡Smith, Samuel. Bank of Liverpool, Liverpool.

1866 ‡Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.

1873 ‡Smith, Swire. Lowfield, Keighley, Yorkshire.

1867 ‡Smith, Thomas (Sheriff). Dundee.

1867 ‡Smith, Thomas. Pole Park Works, Dundee.

1859 ‡Smith, Thomas James, F.G.S., F.C.S. Hessle, near Hull.

1852 ‡Smith, William. Eglinton Engine Works, Glasgow.

1857 §SMITH, WILLIAM, C.E., F.G.S., F.R.G.S. 18 Salisbury-street, Adelphi, London, W.C.

1875 §Smith, William. Sundon House, Clifton, Bristol.

1876 §Smith, William. 12 Woodside-place, Glasgow.

1874 ‡Smoothy, Frederick. Bocking, Essex.

1850 *SMYTH, CHARLES PIAZZI, F.R.S.E., F.R.A.S., Astronomer Royal for Scotland, Professor of Astronomy in the University of Edinburgh. 15 Royal-terrace, Edinburgh.

1870 ‡Smyth, Colonel H. A., R.A. Barrackpore, near Calcutta.

1874 ‡Smyth, Henry, C.E. Downpatrick, Ireland.

1870. ‡Smyth, H. L. Crabwall Hall, Cheshire.

1857. *SMYTH, JOHN, jun., M.A., C.E., F.M.S. Lenaderg, Banbridge, Ireland.

Year of Election

1868 ‡Smyth, Rev J. D. Hurst. 13 Upper St. Giles's-street, Norwich

1864. ‡SMYTH, WARINGTON W., M A, F R S, F.G.S, F.R.G.S, Lecturer on Mining and Mineralogy at the Royal School of Mines, and *Inspector of the Mineral Property of the Crown* 92 Inverness-terrace, Bayswater, London, W.

1854. †Smythe, Major-General W J, R.A, F.R S. Athenæum Club, Pall Mall, London, S W.

Soden, John Athenæum Club, Pall Mall, London, S W.

*SOLLY, EDWARD, F.R S., F.L S., F G S, F.S.A. Park House, Sutton, Surrey.

*SOPWITH, THOMAS, M.A, F.R S, F G.S, F.R G.S. 103 Victoria-street, Westminster, S.W.

Sorbey, Alfred. The Rookery, Ashford, Bakewell

1859. *SORBY, H CLIFTON, F R S, F G S Broomfield, Sheffield.

1865. *Southall, John Tertius Leominster

1859 ‡Southall, Norman. 44 Cannon-street West, London, E.C.

1856 ‡Southwood, Rev. T. A. Cheltenham College.

1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham

1863. *Spark, H King. Skirsgill Park, Penrith.

1859. ‡*Spence, Rev James, D D 6 Clapton-square, London, N E*

*Spence, Joseph 60 Holgate Hill, York

1860 *Spence, J Berger Erlington House, Manchester

1854. §Spence, Peter Pendleton Alum Works, Newton Heath; and Smedley Hall, near Manchester

1861. ‡Spencer, John Frederick. 28 Great George-street, London, S W.

1861 *Spencer, Joseph Springbank, Old Trafford, Manchester.

1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham

1875 §Spencer, W. H. Richmond-hill, Clifton, Bristol.

1871. ‡Spicer, George. Broomfield, Halifax.

1864. *Spicer, Henry, B A., F.L S, F G S 14 Aberdeen Park, Highbury, London, N.

1864. §Spicer, William R. 10 New Bridge-street, Blackfriars, London, E C

1847. *Spiers, Richard James, F S.A Huntercombe, Oxford.

1868. *Spiller, Edmund Pim. 3 Furnival's Inn, London, E.C.

1864. *SPILLER, JOHN, F.C.S. 2 St Mary's-road, Canonbury, London, N.

1846. *SPOTTISWOODE, WILLIAM, M.A, LL D., F R.S., F.R.A.S., F.R G S. 41 Grosvenor-place, London, S W.

1864. *Spottiswoode, W. Hugh. 41 Grosvenor-place, London, S W

1854. *SPRAGUE, THOMAS BOND 29 Buckingham-terrace, Edinburgh.

1853. ‡Spratt, Joseph James West-parade, Hull.

Square, Joseph Elliot, F G.S 24 Portland-place, Plymouth.

*Squire, Lovell. The Observatory, Falmouth.

1858. *STAINTON, HENRY T., F.R.S., F L.S., F.G.S. Mountsfield, Lewisham, S.E.

1865. §STANFORD, EDWARD C. C. Thornloe, Partick Hill, near Glasgow.

1837. Staniforth, Rev. Thos. Storrs, Windermere.

STANLEY, The Very Rev. ARTHUR PENRHYN, D.D., F.R.S., Dean of Westminster. The Deanery, Westminster, London, S.W.

Stapleton, H. M. 1 Mountjoy-place, Dublin.

1866. ‡Starey, Thomas R. Daybrook House, Nottingham.

1876. §Starling, John Henry, F.C.S. The Avenue, Erith, Kent.

Staveley, T. K. Ripon, Yorkshire.

1873. *Stead, Charles. Saltaire, Bradford, Yorkshire.

1857. ‡Steale, William Edward, M.D. 15 Hatch-street, Dublin.

Year of
Election

1870 ‡Stearn, C H 3 Elden terrace, Rock Ferry, Liverpool
1863 §Steele, Rev Dr 35 Sydney-buildings Bath
1873 §Steinthal G A 15 Hallfield road Bradford Yorkshire
1861 ‡Steinthal H M Hollywood Fallowfield, near Manchester
STENHOUSE JOHN LL D F R S, F C S 17 Rodney-street, Pentonville, London N
1872 ‡Stennett Mrs Eliza 2 Clarendon terrace, Brighton
1861 *Stern S J Littlegrove East Barnet, Herts
1863 §Sterriker John Driffield, Yorkshire
1872 §Sterry William Union Club Pall Mall London S W
1876 §Steuart Walter City Bank Pollokshields near Glasgow
1870 *Stevens Miss Anna Maria Belmont Devizes road Salisbury
1861 *Stevens Henry F S A, F R G S 4 Trafalgar square, London, W C
1863 *Stevenson Archibald 2 Wellington crescent South Shields.
1850 ‡*Stevenson David*
1868 ‡Stevenson Henry F L S Newmarket road Norwich
1863 *STEVENSON JAMES C M P F C S Westoe South Shields
1876 *Stewart Alexander B Rawcliffe Lodge Langside, Glasgow
1865 ‡STEWART BALFOUR M A LL D F R S Professor of Natural Philosophy in Owens College Manchester
1864 ‡STEWART CHARLES F L S 10 Princess square, Plymouth
1866 *Stewart Henry Hutchinson, M D M R I A 75 Eccles street, Dublin
1875 **Stewart James B A Lynwood House Long Ashton, Bristol*
1847 ‡Stewart Robert M D The Asylum Belfast
1876 §Stewart William Violet Grove House St George's road, Glasgow
1867 ‡Stirling Dr D Perth
1868 ‡Stirling Edward 34 Queen's gardens Hyde Park London, W
1876 §Stirling William M D D Sc The University, Edinburgh
1867 *Stirrup Mark F G S 14 Atkinson street Deansgate, Manchester
1865 *Stock Joseph S Showell Green, Sparkhill, near Birmingham
Stoddart George
1864 §STODDART WILLIAM WALTER, F G S, F C S 7 King square, Bristol
1854 ‡Stoess, Le Chevalier Ch de W (Bavarian Consul) Liverpool
*STOKES GEORGE GABRIEL M A D C L, LL D, Sec R S, Lucasian Professor of Mathematics in the University of Cambridge Lensfield Cottage Cambridge
1862 ‡STONE, EDWARD JAMES M A F R S, F R A S, Astronomer Royal at the Cape of Good Hope Cape Town
1874 §Stone, J F M Harris, B A, F L S, F C S St Peter's College, Cambridge
1876 §Stone, Octavius C, F R G S Springfield Nuneaton
1859 ‡*Stone Dr William H 13 Vigo street, London, W*
1857 ‡STONEY, BINDON B M R I A, Engineer of the Port of Dublin 42 Wellington road Dublin
1861 *STONEY, GEORGE JOHNSTONE, M A, F R S, M R I A, Secretary to the Queen's University, Ireland Weston House, Dundrum, Co Dublin
1876 §Stopes, Henry F G S East Hill Colchester
1854 ‡Store, George Prospect House, Fairfield, Liverpool
1873 ‡Storr, William The 'Times' Office, Printing-house-square, London, E C
1867 ‡STORRAR, JOHN M D Heathview, Hampstead, London, N W
1859 §Story, James 17 Bryanston-square, London, W
1874 §Stott, William Greetland, near Halifax, Yorkshire

Year of Election

1871. *STRACHEY, Major-General RICHARD, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S. Stowey House, Clapham Common, London, S.W.
1876. §Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.
*Strickland, Charles. Loughglyn House, Castlerea, Ireland.
Strickland, William. French-park, Roscommon, Ireland.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1867. ‡Stronner, D. 14 Princess-street, Dundee.
1876. *Struthers, John, M.D., Professor of Anatomy in the University of Aberdeen.
1876. *Stuart, Charles Maddock. Sudbury Hill, Harrow.
1872. *Stuart, Rev. Edward A. Thorpe, near Norwich.
1864. ‡Style, Sir Charles, Bart. 102 New Sydney-place, Bath.
1873. §Style, George, M.A. Giggleswick School, Yorkshire.
1857. ‡SULLIVAN, WILLIAM K., Ph.D., M.R.I.A. Royal College of Science for Ireland, and 53 Upper Leeson-road, Dublin.
1873. ‡Sutcliffe, J. W. Sprink Bank, Bradford, Yorkshire.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne.
1862. *SUTHERLAND, GEORGE GRANVILLE WILLIAM, Duke of, K.G., F.R.S., F.R.G.S. Stafford House, London, S.W.
1855. ‡*Sutton, Edwin.*
1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1876. §Swan, David, jun. Braeside, Maryhill, Glasgow.
1861. *Swan, Patrick Don S. Kirkcaldy, N.B.
1862. *SWAN, WILLIAM, LL.D., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews. 2 Hope-street, St. Andrews, N.B.
1862. *Swann, Rev. S. Kirke. Gedling, near Nottingham.
Sweetman, Walter, M.A., M.R.I.A. 4 Mountjoy-square North, Dublin.
1870. *Swinburne, Sir John, Bart. Capheaton, Newcastle-on-Tyne.
1863. ‡Swindell, J. S. E. Summerhill, Kingswinford, Dudley.
1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1863. ‡SWINHOE, ROBERT, F.R.S., F.R.G.S., Her Majesty's Consul at Taiwan. 33 Carlyle-square, S.W., and Oriental Club, London, W.
1873. §Sykes, Benjamin Clifford, M.D. Cleckheaton.
1847. ‡Sykes, H. P. 47 Albion-street, Hyde Park, London, W.
1862. ‡Sykes, Thomas. Cleckheaton, near Leeds.
1847. ‡Sykes, Captain W. H. F. 47 Albion-street, Hyde Park, London, W.
SYLVESTER, JAMES JOSEPH, M.A., LL.D., F.R.S. Athenæum Club, London, S.W.
1870. §SYMES, RICHARD GLASCOTT, A.B., F.G.S. Geological Survey of Ireland, 14 Hume-street, Dublin.
1856. *Symonds, Frederick, M.A., F.R.C.S. 35 Beaumont-street, Oxford.
1859. ‡Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi, London, W.C.
1860. ‡SYMONDS, Rev. W.S., M.A., F.G.S. Pendock Rectory, Worcestershire.
1859. §SYMONS, G. J., Sec. M.S. 62 Camden-square, London, N.W.
1855. *SYMONS, WILLIAM, F.C.S. 26 Joy-street, Barnstaple.
Synge, Francis. Glanmore, Ashford, Co. Wicklow.
1872. ‡Synge, Major-General Millington, R.E., F.S.A., F.R.G.S. United Service Club, Pall Mall, London, S.W.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.

Year of
Election.

1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh
1867. ‡Tait, P. M., F.R.G.S. Oriental Club, Hanover-square, London, W.
§Talbot, William Hawkshead. Hartwood Hall, Chorley, Lancashire
TALBOT, WILLIAM HENRY FOX, M.A., LL.D., F.R.S., F.L.S. Lacock Abbey, near Chippenham
1874. §Talmage, C. G. Leyton Observatory, Essex, E.
Taprell, William. 7 Westbourne-crescent, Hyde Park, London, W.
1866. ‡Tarbottom, Marriott Ogle, M.I.C.E., F.G.S. Newstead-grove, Nottingham
1861. *Tarratt, Henry W. Mountfield, Grove Hill, Tunbridge Wells
1856 ‡Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1857. *Tate, Alexander. 2 Queen's-elms, Belfast
1863. ‡Tate, John. Alnmouth, near Alnwick, Northumberland.
1870. ‡Tate, Norman A. 7 Nivell-chambers, Fazackerley-street, Liverpool
1865. ‡*Tate, Thomas.*
1858 *Tatham, George. Springfield Mount, Leeds.
1876. §Tatlock, Robert R. 26 Burnbank-gardens, Glasgow
1864. *TAWNEY, EDWARD B., F.G.S. 16 Royal York-crescent, Clifton, Bristol.
1871. ‡Tayler, William, F.S.A., F.S.S. 28 Park-street, Grosvenor-square, London, W.
1874. ‡Taylor, Alexander O'Driscoll. 3 Upper-crescent, Belfast.
1867. ‡Taylor, Rev. Andrew. Dundee.
Taylor, Frederick. Laurel-cottage, Rainhill, near Prescot, Lancashire.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
*TAYLOR, JOHN, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1861. *Taylor, John, jun. 6 Queen-street-place, Upper Thames-street, London, E.C.
1873. §TAYLOR, JOHN ELLOR, F.L.S., F.G.S. The Mount, Ipswich
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
Taylor, Captain P. Meadows, in the Service of His Highness the Nizam. Harold Cross, Dublin.
*TAYLOR, RICHARD, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1876. §Taylor, Robert. 70 Bath-street, Glasgow.
1870. §Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
*Taylor, William Edward. Millfield House, Enfield, near Accrington
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
1869. ‡Teesdale, C. S. M. Whyke House, Chichester
1876. §Temperley, Ernest. Queen's College, Cambridge
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
*TENNANT, JAMES, F.G.S., F.R.G.S., Professor of Mineralogy in King's College. 149 Strand, London, W.C.
1857. ‡Tennison, Edward King. Kildare-street Club House, Dublin.
1866. ‡Thackeray, J. L. Arno Vale, Nottingham.
1859. ‡Thain, Rev. Alexander. New Machar, Aberdeen.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡THISELTON-DYER, W. T., M.A., B.Sc., F.L.S. 10 Gloucester-road, Kew, W.
1855. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1875. *THOMAS, CHRISTOPHER JAMES. Drayton Lodge, Redland, Bristol.

Year of Election

Thomas, George Brislington, Bristol
1875 §Thomas, Herbert 2 Great George-street, Bristol
1869 ‡Thomas, H D Fore-street, Exeter
1869 ‡Thomas, J Henwood, F R G S Custom House, London, E C
1875 §Thompson, Arthur 12 St Nicholas street, Hereford
1863 ‡Thompson, Rev Francis St Giles's, Durham
1858 *Thompson, Frederick South-parade, Wakefield
1859 §Thompson, George, jun Pidsmedden, Aberdeen
Thompson, Harry Stephen Kirby Hall, Great Ouseburn, Yorkshire
1870 ‡THOMPSON, Sir HENRY 5 Wimpole-street, London, W
Thompson, Henry Stafford Fairfield, near York
1861 *Thompson, Joseph Woodlands, Fulshaw, near Manchester
1864 ‡THOMPSON, Rev JOSEPH HESSELGRAVE, B A Cradley, near Brierley-hill
Thompson, Leonard Sheriff Hutton Park, Yorkshire
1873 ‡Thompson, M W Guiseley, Yorkshire
1876 *Thompson, Richard St Paul's square, York
1874 §Thompson, Robert Royal terrace, Belfast
1870 §Thompson, Silvanus P University College, Bristol
1863 ‡Thompson, William 11 North terrace, Newcastle-on-Tyne
1867 ‡Thoms, William Magdalen yard-road, Dundee
1855 ‡THOMSON, ALLEN, M D, LL D, F R S L & E, Professor of Anatomy in the University of Glasgow (PRESIDENT ELECT) The University, Glasgow
1872 ‡*Thomson, Gordon A Bedeque House, Belfast*
Thomson, Guy Oxford
1850 *THOMSON, Professor JAMES, M A, LL D, C E, F R S E The University, Glasgow
1855 ‡*Thomson, James 82 West Nile-street, Glasgow*
1868 §THOMSON, JAMES, F G S 276 Eglinton street, Glasgow
1876 §Thomson, James 276 Eglinton street, Glasgow
*Thomson, James Gibson 14 York place, Edinburgh
1876 §Thomson, James R Dalmuir House, Dalmuir, Glasgow
1874 §Thomson, John Harbour Office, Belfast
1871 *Thomson, John Millar, F C S King's College, London, W C
1863 ‡*Thomson, M 8 Meadow-place, Edinburgh*
1872 ‡*Thomson, Peter 34 Granville street, Glasgow*
1871 ‡Thomson, Robert, LL B 12 Rutland-square, Edinburgh
1865 ‡Thomson, R W, C E, F R S E 3 Moray-place, Edinburgh
1850 ‡THOMSON, THOMAS, M D, F R S, F L S The Cottage, West Farleigh, Maidstone
1847 *THOMSON, Sir WILLIAM, M A, LL D, D C L, F R S L & E, Professor of Natural Philosophy in the University of Glasgow The University, Glasgow
1874 §Thomson, William, F R S L, F C S Royal Institution, Manchester
1876 §Thomson, William 6 Mansfield-place, Edinburgh
1871 §Thomson, William Burnes, F R S E 1 Ramsay-gardens, Edinburgh
1870 ‡*Thomson, W C, M D*
1850 ‡THOMSON, Sir WYVILLE T C, LL.D, F R S., F G S, Regius Professor of Natural History in the University of Edinburgh 20 Palmerston-place, Edinburgh
1871. ‡Thorburn, Rev David, M A 1 John's-place, Leith.
1852 ‡Thorburn, Rev William Reid, M A. Starkies, Bury, Lancashire
1866 ‡Thornton, James Edwalton, Nottingham
*Thornton, Samuel, J.P Oakfield, Moseley, near Birmingham.
1867 ‡Thornton, Thomas Dundee.

Year of
Election.

1845 ‡Thorp, Dr. Disney. Suffolk Lawn, Cheltenham.
1871 ‡Thorp, Henry. Briarleigh, Sale, near Manchester.
1864 *Thorp, William, B.Sc., F.C.S. 39 Sandringham-road, Kingsland, London, E.
1871 §Thorpe, T. E., Ph.D., F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the Yorkshire College of Science, Leeds.
1868 ‡Thuillier, Colonel, R.A., C.S.I., Surveyor-General of India. 46 Park-street, Calcutta.
Tl[illegible]ha[illegible], John, M.D. Dev[illegible]
1870 ‡Tichborne, Charles R. C., F.C.S. Apothecaries' Hall of Ireland, Dublin.
1873 *Tiddeman, R. H., M.A., F.G.S. 28 Jermyn-street, London, S.W.
1874 §Tilden, William A., D.Sc., F.C.S. Clifton College, Bristol.
1873 ‡Tilghman, B. C. Philadelphia, United States.
1865 §Timmins, Samuel, J.P., F.S.A. Elvetham-road, Edgbaston, Birmingham.
Tinker, Ebenezer. Mealhill, near Huddersfield.
*Tinné, John A., F.R.G.S. Briarley, Aigburth, Liverpool.
18[illegible] §T[illegible]d[illegible], Rev. Dr. [illegible]lor Hall, Forest Hill, London, S.E.
1861 *Todhunter, Isaac, M.A., F.R.S., Principal Mathematical Lecturer at St. John's College, Cambridge. Brookside, Cambridge.
Todhunter, J. 3 College-green, Dublin.
1857 ‡Tombe, Rev. H. J. Ballyfree, Ashford, Co. Wicklow.
1856 ‡Tomes, Robert Fisher. Welford, Stratford-on-Avon.
1864 *Tomlinson, Charles, F.R.S., F.C.S. 3 Ridgmount-terrace, Highgate, London, N.
1863 ‡Tone, John F. Jesmond-villas, Newcastle-on-Tyne.
1865 §Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
186[illegible] §Tonks, William Henry. The Rookery, Sutton Coldfield.
1873 *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.
1861 *Topham, John, A.I.C.E. High Elms, 265 Mare-street, Hackney, London, E.
1872 *Topley, William, F.G.S., A.I.C.E. Geological Survey Office, Jermyn-street, London, S.W.
1875 §Torr, Charles Hawley. Victoria-street, Nottingham.
1863 ‡Torrens, Colonel Sir R. R., K.C.M.G. 2 Gloucester-place, Hyde Park, London, W.
1859 ‡Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus, N.B.
Towgood, Edward. St. Neot's, Huntingdonshire.
1873 ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875 ‡Townsend, Charles. Avenue House, Cotham Park, Bristol.
1860 ‡*Townsend, John.*
1857 ‡Townsend, Rev. Richard, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.
1861 ‡Townsend, William. Attleborough Hall, near Nuneaton.
1854 ‡Towson, John Thomas, F.R.G.S. 47 Upper Parliament-street, Liverpool; and Local Marine Board, Liverpool.
1876 *Trail, J. W. H., M.A., M.B., F.L.S. King's College, Old Aberdeen.
1859 ‡*Trail, Samuel, D.D., LL.D.*
1870 ‡Traill, William A., M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1875 §Trapnell, Caleb. Severnleigh, Stoke Bishop.
1868 ‡Traquair, Ramsay H., M.D., Professor of Zoology. Museum of Science and Art, Edinburgh.

Year of Election

1865 ‡Travers, William, F.R.C.S. 1 Bath-place, Kensington, London, W.

Tregelles, Nathaniel. Neath Abbey, Glamorganshire.

1868 ‡Trehane, John. Exe View Lawn, Exeter.

1869 ‡Trehane, John, jun. Bedford-circus, Exeter.

1870 ‡Trench, Dr. Municipal Offices, Dale-street, Liverpool.

Trench, F. A. Newlands House, Clondalkin, Ireland.

*TREVELYAN, ARTHUR, J.P. Tyneholm, Pencaitland, N.B.

TREVELYAN, SIR WALTER CALVERLEY, Bart., M.A., F.R.S.E., F.G.S., F.S.A., F.R.G.S. Athenæum Club, London, S.W.; Wallington, Northumberland; and Nettlecombe, Somerset.

1871 ‡TRIBE, ALFRED, F.C.S. 14 Denbigh-road, Bayswater, London, W.

1871 ‡TRIMEN, ROLAND, F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.

1860 §TRISTRAM, Rev. HENRY BAKER, M.A., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.

1869 ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.

1864 ‡*Truell, Robert. Ballyhenry, Ashford, Co. Wicklow.*

1869 ‡Tucker, Charles. Marlands, Exeter.

1847 *Tuckett, Francis Fox. 10 Baldwin-street, Bristol.

Tuke, James H. Bank, Hitchin.

1871 ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.

1867 ‡Tulloch, The Very Rev. Principal, D.D. St. Andrews, Fifeshire.

1854 ‡TURNBULL, JAMES, M.D. 86 Rodney-street, Liverpool.

1855 §Turnbull, John. 37 West George-street, Glasgow.

1856 ‡Turnbull, Rev. J. C. 8 Bayshill-villas, Cheltenham.

1871 §Turnbull, William. 14 Lansdowne-crescent, Edinburgh.

1873 *Turner, George. Horton Grange, Bradford, Yorkshire.

Turner, Thomas, M.D. 31 Curzon-street, Mayfair, London, W.

1875 ‡Turner, Thomas, F.S.S. Ashley House, Kingsdown, Bristol.

1863 *TURNER, WILLIAM, M.B., F.R.S.E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.

1842 Twamley, Charles, F.G.S. 11 Regent's Park-road, London, N.W.

1847 ‡TWISS, Sir TRAVERS, D.C.L., F.R.S., F.R.G.S. 3 Paper-buildings, Temple, London, E.C.

1865 §TYLOR, EDWARD BURNETT, F.R.S. Linden, Wellington, Somerset.

1858 *TYNDALL, JOHN, D.C.L., LL.D., Ph.D., F.R.S., F.G.S., Professor of Natural Philosophy in the Royal Institution. Royal Institution, Albemarle-street, London, W.

1861 *Tysoe, John. 28 Seedley-road, Pendleton, near Manchester.

1876 *Unwin, W. C., A.I.C.E., Professor of Hydraulic Engineering, Cooper's Hill, Middlesex.

1872 ‡Upward, Alfred. 11 Great Queen-street, Westminster, London, S.W.

1855 ‡*Ure, John.*

1876 §Ure, John, F. 6 Claremont-terrace, Glasgow.

1859 ‡*Urquhart, Rev. Alexander.*

1859 ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.

1866 ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.

1873 §Uttley, Hiram. Burnley.

*Vance, Rev. Robert. 24 Blackhall-street, Dublin.

1863 ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S.M. Tunisienne, Geneva.

Year of
Election

1854 ‡Varley, Cromwell F, F R S Fleetwood House, Beckenham, Kent
1868 §Varley, Frederick H, F R A S Mildmay Park Works, Mildmay Avenue, Stoke Newington London, N
1865 *VARLEY S ALFRED Hatfield, Herts
1870 ‡Varley Mrs S A Hatfield, Herts
1860 ‡Varwell, P Alphington-street, Exeter
1875 §Vaughan, Miss Burlton Hall, Shrewsbury
1863 ‡*Vauvert, de Mean A, Vice-Consul for France Tynemouth*
1849 *Vaux, Frederick Central Telegraph Office, Adelaide, South Australia
1873 *Verney, Captain Edmund H, R N Rhianva Bangor North Wales
Verney, Sir Harry, Bart Lower Claydon Buckinghamshire
1866 ‡Vernon, Rev J H Harcourt Cotgrave Rectory near Nottingham
Vernon, George John, Lord 32 Curzon street, London, W, and Sudbury Hall, Derbyshire
1854 *VERNON, GEORGE V, F R A S 1 Osborne-place, Old Trafford, Manchester
1864 *VICARY, WILLIAM F G S The Priory, Colleton-crescent, Exeter
1868 ‡Vincent Rev William Postwick Rectory near Norwich
1875 §Vines David F R A S Observatory House, Somerset-street, Kingsdown Bristol
1856 ‡VIVIAN, EDWARD, B A Woodfield, Torquay
*VIVIAN, H HUSSEY, M P, F G S Park Wern, Swansea, and 27 Belgrave-square London S W
1856 §VOELCKER, J CH AUGUSTUS, Ph D, F R S, F C S Professor of Chemistry to the Royal Agricultural Society of England 39 Argyll-road, Kensington, London, W
1875 ‡Volckman, Mrs E G 43 Victoria road Kensington, London, W
1875 §Volckman, William 43 Victoria road, Kensington, London, W
‡Vose, Dr James Gambier-terrace Liverpool

1875 ‡*Wace, Rev A St Paul's, Maidstone Kent*
1860 §Waddingham, John Guiting Grange, Winchcombe, Gloucestershire
1859 ‡Waddington, John New Dock Works, Leeds
1870 §WAKE, CHARLES STANILAND 70 Wright-street, Hull.
1855 *Waldegrave, The Hon Granville 26 Portland-place, London, W.
1873 ‡Wales, James 4 Mount Royd, Manningham, Bradford, Yorkshire.
1869 *Walford, Cornelius 86 Belsize-park-gardens London, N W
1849 §WALKER, CHARLES V, F R S, F R A S Fernside Villa, Redhill, near Reigate
Walker, Sir Edward S Berry Hill, Mansfield
Walker, Frederick John The Priory, Bathwick, Bath
1866 ‡Walker, H Westwood, Newport, by Dundee
1859 ‡*Walker, James*
1855 ‡Walker, John 1 Exchange court Glasgow
1842 *Walker, John Thorncliffe, Kenilworth-road, Leamington
1866 *WALKER, J F, M A, F C P S, F C S, F G S, F L S 16 Gillygate, York
1867 *Walker, Peter G. 2 Airlie-place, Dundee
1866 ‡Walker, S D 38 Hampden-street, Nottingham.
1869 *Walker, Thomas F W, M A, F G S, F R G S 3 Circus, Bath
Walker, William 47 Northumberland-street, Edinburgh
1869 ‡Walkey, J F C High-street, Exeter
1863 ‡WALLACE, ALFRED RUSSEL, F R G S, F L S Rosehill, Dorking
1859 ‡WALLACE, WILLIAM, Ph D, F C S Chemical Laboratory, 138 Bath-street, Glasgow.

Year of
Election

1857 ‡Waller, Edward. Lasenderry, Aughnacloy, Ireland.
1862. ‡*Wallich, George Charles, M.D., F.L.S. 60 Holland-road, Kensington, London, W.*
Wallinger, Rev. William.
1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., M.P., F.R.S. Ealing, London, W.
1857. ‡Walsh, Albert Jasper, F.R.C.S.I. 89 Harcourt-street, Dublin.
Walsh, John (Prussian Consul). 1 Sir John's Quay, Dublin.
1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.
Walton, Thomas Todd. Mortimer House, Clifton, Bristol.
1863 †Wanklyn, James Alfred. 117 Charlotte-street, Fitzroy-square, London, W.
1872. ‡Warburton, Benjamin. Leicester.
1874 §Ward, F. D. 6 University-square, Belfast.
1874 §Ward, John, F.R.G.S. Royal Ulster Works, Chlorine, Belfast.
1857. ‡Ward, John S. Prospect-hill, Lisburn, Ireland.
Ward, Rev. Richard, M.A. 12 Eaton-place, London, S.W.
1863 †Ward, Robert. Dean-street, Newcastle-on-Tyne.
*Ward, William Sykes, F.C.S. 12 Bank-street, and Denison Hall, Leeds.
1867. ‡Warden, Alexander J. Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1865. ‡Waring, Edward John, M.D., F.L.S. 49 Clifton-gardens, Maida-vale, London, W.
1864. *Warner, Edward. 49 Grosvenor-place, London, S.W.
1872. *Warner, Thomas. 47 Sussex-square, Brighton.
1856. ‡Warner, Thomas H. Lee. Tiberton Court, Hereford.
1875. ‡Warren, Algernon. Naseby House, Pembroke-road, Clifton, Bristol.
1865. *Warren, Edward P. 13 Old-square, Birmingham.
1869. ‡*Warren, James L.*
Warwick, William Atkinson. Wyddrington House, Cheltenham.
1856 ‡Washbourne, Buchanan, M.D. Gloucester.
1870. §Waterhouse, A. Willenhall House, Barnet, Herts.
*WATERHOUSE, JOHN, F.R.S., F.G.S., F.R.A.S. Wellhead, Halifax, Yorkshire.
1875. *Waterhouse, Captain J. Surveyor-General's Office, Calcutta. (Care of Messrs. Trubner & Co., Ludgate-hill, London, E.C.)
1854 ‡Waterhouse, Nicholas. 5 Rake-lane, Liverpool.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1875. §Waters, Arthur W., F.G.S. Woodbrook, Alderley Edge, near Birmingham.
1875 §Watherston, Alexander Law, M.A., F.R.A.S. Brentwood, Essex.
1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1855. ‡Watson, Ebenezer. 16 Abercromby-place, Glasgow.
1867. ‡Watson, Frederick Edwin. Thickthorn House, Cringleford, Norwich.
*WATSON, HENRY HOUGH, F.C.S. 227 The Folds, Bolton-le-Moors.
WATSON, HEWETT COTTRELL. Thames Ditton, Surrey.
1873. *Watson, Sir James. 9 Woodside-terrace, Glasgow.
1859. ‡WATSON, JOHN FORBES, M.A., M.D., F.L.S. India Museum, London, S.W.
1863. ‡Watson, Joseph. Bensham-grove, near Gateshead-on-Tyne.
1863. ‡Watson, R. S. 101 Pilgrim-street, Newcastle-on-Tyne.
1867. ‡Watson, Thomas Donald. 41 Cross-street, Finsbury, London, E.C.
1869. ‡Watt, Robert B. E., C.E., F.R.G.S. Ashley-avenue, Belfast.
1861. ‡Watts, Sir James. Abney Hall, Cheadle, near Manchester.
1875. *Watts, John, D.Sc. 57 Baker-street, Portman-square, London, W.

Year of Election

1846 §Watts, John King, F.R.G.S. Market-place, St. Ives, Hunts.

1870. §Watts, William. Oldham Corporation Waterworks, Piethorn, near Rochdale

1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.

1858 ‡Waud, Major E. Manston Hall, near Leeds.

Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.

1862 §WAUGH, Major-General Sir ANDREW SCOTT, R.E., F.R.S., F.R.A.S., F.R.G.S. 7 Petersham-terrace, Queen's-gate-gardens, London, W.

1859 ‡Waugh, Edwin. Sager-street, Manchester.

*WAVENEY, The Right Hon. Lord, F.R.S. 7 Audley-square, London, W.

*WAY, J. THOMAS, F.C.S. 9 Russell-road, Kensington, London, S.W.

1860 ‡Way, Samuel James. Adelaide, South Australia.

1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.

*WEBB, Rev. THOMAS WILLIAM, M.A., F.R.A.S. Hardwick Vicarage, Hay, South Wales.

1866 *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.

1859 ‡Webster, John. 42 King-street, Aberdeen.

1862 ‡Webster, John Henry, M.D. Northampton.

1834 †Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.

1845. ‡*Wedgewood, Hensleigh. 17 Cumberland-terrace, Regent's Park, London, N.W.*

1854. †Weightman, William Henry. Farn Lea, Seaforth, Liverpool.

1865. ‡Welch, Christopher, M.A. University Club, Pall Mall East, London, S.W.

1867 §Weldon, Walter. Abbey Lodge, Merton, Surrey.

1870 §Weldon, W. F. R. Abbey Lodge, Merton, Surrey.

1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.

Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.

1864. *Were, Anthony Berwick. Whitehaven, Cumberland.

1865. †*Wesley, William Henry.*

1853. ‡West, Alfred. Holderness-road, Hull.

1870. ‡West, Captain E. W. Bombay.

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1870 §Westgarth, William. 10 Bolton-gardens, South Kensington, London, W.

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Westhead, John. Manchester.

1842. *Westhead, Joshua Proctor Brown. Lea Castle, near Kidderminster.

1857. *Westley, William. 24 Regent-street, London, S.W.

1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.

1860 §Weston, James Woods. Belmont House, Pendleton, Manchester.

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1858. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.

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1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N W.
1847 ‡Wheeler, Edmund, F R A.S 48 Tollington-road, Holloway, London, N.
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1861 *Whitehead, Peter Ormerod Belmont, Rawtenstall, Manchester
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1872 ‡*Winter G K*
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Year of
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1870 *YOUNG, JAMES, F R S, F C S Kelly, Wemyss Bay, by Greenock
Young, John. Taunton, Somersetshire
1876 §YOUNG JOHN, M.D, Professor of Natural History in the University of Glasgow 38 Cecil-street, Hillhead, Glasgow
1876 *Young, John, F.C S Kelly, Wemyss Bay, by Grenock.
Younge, Robert, F L S. Greystones, near Sheffield.
1868 ‡Youngs, John Richmond Hill, Norwich
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1871. ‡YULE, Colonel HENRY, C.B. East India United Service Club, St. James's-square, London, S.W.

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August 1877.

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